BACKGROUND REPORT
ON
LEVEES

A Report to the Delta Protection Commission

JANUARY 1994
REPRINTED: FEBRUARY 2001
Web Version March 2001

Table of Contents

Introduction……………………………………………………………………………1

Chapter I: History of Levee Construction in the Delta 5

1. Natural Levees..................................5
2. Events Leading to Delta Reclamation............5
3. Early Reclamation Efforts......................5
   a. Levee Building: 1850-1880...................6
   b. Chinese Laborers and Levee Building.........8
   c. Reclamation Period from 1880 to Early 1990's 9

4. The Delta's First Reclamation Districts 9

Chapter II: Modern Delta Levees 11

1. Flood Control 11
   a. Flood Control Projects 11
   b. Flood Insurance Programs 11
2. Project Levees 12
3. Direct Agreement Levees 13
4. Non-Project Levees 13

Chapter III: Maintenance of Levees: Vegetation ..21

1. Non-Project Levees 21
2. Project Levees 25
3. Levees as Habitat 27

Chapter IV: Levee Maintenance and Upgrades: Physical 29

1. Delta Flood Hazard Mitigation Plan 29
2. Materials for Levee Repair 30
3. Future Levee Maintenance Programs 31
4. Current Findings on Levee Maintenance 32

Chapter V: Levee Maintenance and Upgrades: Funding 35

1. Historic Maintenance of Non-Project Levees ...35
2. The Delta Levee Maintenance Subvention Program.35
   (Way Bill)
3. SB 34: Delta Flood Protection Act 36
4. Emergency Levee Repair 36
5. Future Funding of Levee Maintenance 37

Chapter VI: Regulatory Process for Maintenance, Upgrades and Emergency Repair 39
1. Reclamation District Levee Work 39
2. Emergency Levee Repair Work 40

Chapter VII: Impacts Associated with Levee Failures 43

1. Water Quality in the Delta and for Exports ... 43
2. Loss of Property ... 43
3. Loss of Habitat ... 44

Chapter VIII: Levee Failure Mechanisms ... 45

1. Failure Categories ... 45
   a. Subsidence ... 45
   b. Stability ... 45
   c. Overtopping ... 46
   d. Subsurface Seepage Erosion ... 46
2. Failure Modes ... 46
   a. Cracks and Fractures ... 46
   b. Encroachments ... 47
   c. Erosion ... 47
   d. Deformation ... 48
   e. Seepage ... 49
   f. Sinkholes ... 49
   g. Rodent Burrows ... 49

3. Seismic Issues ... 49

Adopted Findings ... 51

Adopted Policies ... 55

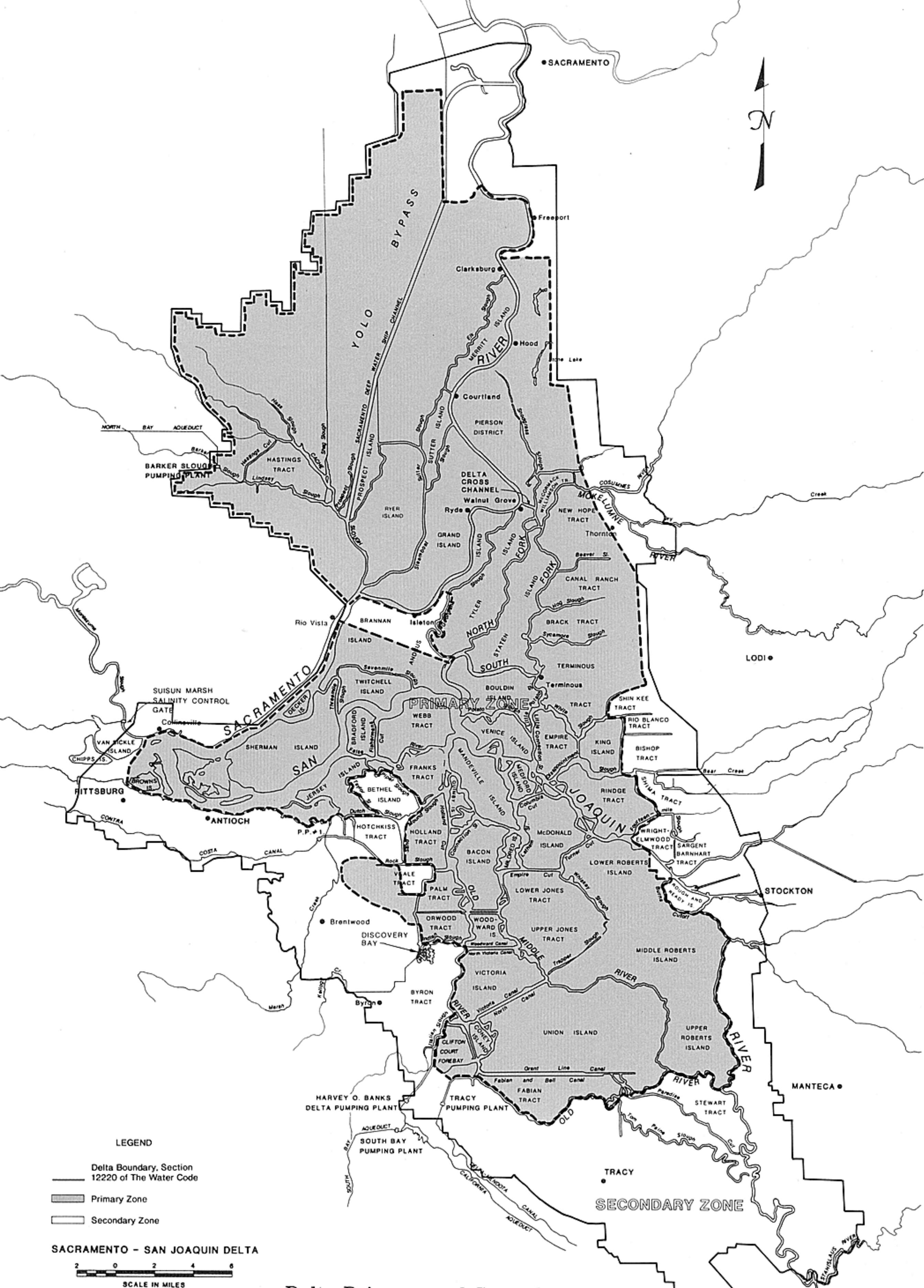
Adopted Recommendations ... 57

Appendix A: Delta Plans and Studies ... 59

References ... 61

List of Figures:

Figure 1: Map of Delta ... 3
Figure 2: Project Levees ... 15
Figure 3: Direct Agreement Levees ... 17
Figure 4: Non-Project Levees ... 19
Figure 5: Draft Vegetation Guidelines ... 23



Delta Primary and Secondary Zones

INTRODUCTION

The Delta Protection Commission is charged with preparation of a land use and resource management plan for the primary management area of the Delta, as designated in the Delta Protection Act (see Figure 1). The Plan is to be adopted by the Commission and forwarded to the five Delta Counties for adoption and implementation through the existing regulatory process.

Counties generally do not regulate construction and maintenance of Delta levees. The federal government has constructed many, which are exempt from local regulatory processes. Non-project levees are constructed and maintained by Reclamation Districts, special districts created by the State specifically to construct and maintain levees. There is a strong inter-relationship between Counties and Reclamation Districts, as Counties gather, hold, and distribute the "taxes" paid by the landowners for levee maintenance costs. In addition, County Supervisors appoint Reclamation District directors if there is no election of directors. Finally, Counties have the responsibility to designate the types and intensity of land uses behind levees and have responsibility to carry out regulation of areas which could be flooded, under federal flood control programs.

Levees are a key physical element, which created and maintain the Delta, as we know it today. Levees allowed low-lying lands to be drained for agriculture, levees protect existing structures, levees define channels used for commercial navigation, levees create the Yolo Bypass-part of a regional flood control program, and levees protect the upland habitat areas on the islands.

Because levees were built at different times, through different construction methods, and to different specifications, the modern challenge has been to go back to the many reclamation districts and develop a universal minimum levee standard of height and cross-section to provide flood protection. Although upstream flood control dams and improved levee maintenance standards have significantly reduced the incidents of over-topping induced levee failures, that mode has remained a concern. Flaws that have caused most modern levee loss are instability of levee foundations, weakness of construction materials, and inconsistent maintenance programs.

Future challenges include long-term funding sources to maintain levees and the need to restore riparian habitat along Delta waterways in a way that strengthens rather than weakens levees.

This report reviews the history of levee construction in the Delta; identifies programs aimed at controlling vegetation on levees, developing a minimum physical standard for Delta levees, and establishing concepts for levee funding; describes the regulatory process for levee maintenance; identifies losses associated with levee failure; and outlines special issues associated with seismic events and overall levee stability issues. An appendix lists past plans developed regarding Delta levees.

Due to limited resources and time constraints allotted the Delta Protection Commission to complete the task of preparing the Plan, this report is based on existing references, updated where feasible through personal contacts with agency staff. Much of the information was extracted from a recent report on Delta levees prepared by the Department of Water Resources for the Bay-Delta Oversight Council. Maps are generously provided by the Department of Water Resources, reprinted from the 1993 Delta Atlas.

CHAPTER I: HISTORY OF LEVEE CONSTRUCTION IN THE DELTA

1. Natural Levees.

The vast marshy area of the historic Delta was made up of low-lying, vegetated wetland islands separated by many channels and sloughs. Along the edges of the channels and sloughs were low natural berms created of deposited sediment. These higher areas were thickly vegetated making the "land" portions of the Delta nearly impassable. Thus, for many years the Delta was avoided and used only as a water passage between San Francisco, Benicia, Vallejo and the new settlements near the confluence of the American River and the Sacramento River.

Some saw the lush vegetation as opportunity for farming and small farmed plots first appeared on the natural levees near Freeport, Sacramento County, and then spread south toward Grand Island. Agriculture in the Stockton area began on higher elevation land near French Camp.

2. Events Leading to Delta Reclamation.

Approximately one-quarter of the swamp and overflowed lands granted to the State of California were in the Sacramento-San Joaquin Delta. This land did not pass to the State all at once; the federal government was to survey the land and the State was then to select or locate sections from the surveyed areas. However, California passed laws in 1855, 1858, 1859, 1863, 1868 and 1872 to provide for the disposal of swamp and overflowed lands prior to the completion of the federal survey.

The manner in which California disposed of its swamp and overflowed lands favored the creation of large holdings. Originally the federal government set a purchase limit of 160 acres. California raised this to 320 acres. Many loopholes existed in California's laws. The 1855 Act was poorly worded and added to the confusion of titles arising from the federal-State dispute. The 1855 Act did not require that land, applied for as swamp and overflowed, be under water or wet part of the year. Even though the main purpose of the grant was to enable the State to get such land reclaimed, persons who purchased the land with cash were not required to reclaim the land at all. An 1859 law reinstated the credit purchase option and increased the acreage limitation to 640 acres. In 1868, acreage limitations were abolished altogether.

Removing acreage limitations on swamp land sales initially led to an increase in the number of large parcels held by individual owners; but after land reclamation began, there was a tendency to subdivide some of the largest tracts. However, there was a floor below which subdivision never fell, because landowners were careful not to subdivide to a point beyond which they would lose control over a reclamation district. The more owners there were, the harder it was to agree on whether and when to build reclamation works. Smaller landowners tended to be more reluctant to share the cost of building levees, drains, and ditches. (Sucheng Chan, This Bitter Sweet Soil, 1986.)

3. Early Reclamation Efforts.

Reclamation in the Delta took place in two stages. The first stage of levee building lasted from the early 1850's to the early 1880's; “wheelbarrow brigades” of Chinese laborers employed by both individual landowners and land reclamation corporations mainly performed the work. The first areas reclaimed in these early decades were the mainland tracts around the periphery of the Delta. These tracts were reclaimed first because their soil had a lower organic content, was less swampy and therefore easier to drain and dike. The second stage involved the use of the clamshell dredge; this machine was introduced in 1879. (Sucheng Chan, <u>This Bitter Sweet Soil</u>, 1986.)

a. <u>Levee Building: 1850-1880.</u> Private individuals using their own funds undertook the earliest reclamation projects on a small scale. As incentive to reclaim their land, the State credited landowner's 20% down payment on the land as payment in full; the credit however was subject to a three-person commission's approval that the landowner had reclaimed and cultivated the land for three years. After 1872 landowners were credited with payment in full if they spent two dollars per acre on reclamation; this practice allowed individual buyers to obtain hundreds or thousands of acres at almost no cost. (Sucheng Chan, <u>This Bitter Sweet Soil</u>, 1986.)

Reclaiming the Delta for agriculture followed Sacramento City's battle with levees against the flooding Sacramento River in 1850. As early as 1849 Bayard Taylor supported embankments to protect the Delta predicting that agriculture would make it one of the most beautiful and productive portions of the Union. During the 1850's, the lower Sacramento River's east bank became a solid string of farms; the farmers, called rimlanders, built low levees atop the natural bank to protect their smallholdings.

Reuben Kercheval began the first reclamation project in the Delta in 1850 on the tip of Grand Island. Before experiencing his first flood he became convinced of the necessity to build levees. He tried to involve his neighbors in this enterprise, but only Sam Brannan (Brannan Island) was interested. Brannan was a merchant who promoted the idea of building levees to protect the City of Sacramento. After the 1852 flood, Kercheval still could not persuade his neighbors to join him in levee building, so he continued on his own.

Kercheval hired a crew of Chinese, Native Americans, and Hawaiians. Kercheval raised the first levee in 1851; it was destroyed. He then hired a larger gang of laborers in 1853 to build a larger levee; it was three feet high, three feet across the crown, thirteen feet wide at the base and twelve miles long. The laborers were paid 13.5 cents per cubic yard of dirt moved by wheelbarrows and shovels. His neighbors finally joined in his efforts, and by 1857 the apex of the island was protected by eighteen miles of dikes of various sizes. After Kercheval's death, his widow carried on his efforts to reclaim all of Grand Island.

The results of reclamation seemed "miraculous" and Kercheval's levee building was quickly imitated. George McKinstry Jr., in 1852, reported cabbages weighing 53 pounds a head. "Small wonder that other lower Sacramento River agriculturists followed Kercheval's lead as farms crept down to Howard Landing and leapfrogged to the Rio Vista sector of the mainland."(Richard Dillon, <u>Delta Country</u> 1982.) Josiah Buckman Greene built a levee on Merritt Island before the flood of 1852, and in 1852 George Andrus hired Chinese levee builders to protect his seven thousand-acre island. Andrus Island's reclamation was completed in 1889. By 1853, dikes, usually atop the natural levees, were protecting the Sacramento River's east shore, parts of Merritt, upper Tyler and Grand Islands plus stretches along the Mokelumne and Calaveras Rivers. These levees were called "shoestring" levees because they were only one foot high.

Uncoordinated levee work began on Sutter Island long before its first reclamation district was formed in 1880, but adequate flood protection did not exist until 1896. Tyler Island, settled in early as 1852, had only its upper tip reclaimed by the end of the 1860's. Andrus Island's reclamation was completed by 1889.

The banks of the Mokelumne, Calaveras and Stanislaus Rivers were occupied by 1852; the next year James Crozier and W.L. Wright pioneered levee building in the area. They hired men to raise eighteen miles of natural banks of Rough and Ready Island, the location of their market garden. Their reclamation cost fifteen hundred dollars per acre at first. Once they "got the hang of it," their reclamation costs dropped to six hundred dollars per acre. By 1857, irregular, discontinuous levees were built up to protect Roberts and Union Islands, and levees were built along the San Joaquin's east bank south of French Camp in 1861.

The Sacramento's lower, flood-prone islands were slow to be developed. Sherman Island's reclamation projects were started in 1859; in the 1890's, the island was still under reclamation with only a small area under cultivation. Merritt Island organized its reclamation district in 1862 and its levees were completed by 1876. In 1865, San Franciscan B.F. Mauldin began reclamation of Ryer Island, but only six miles of levees were built in the sixties.

Reclamation was resumed in the 1880's and 1890's, but reclamation on Ryer Island was not completed until modern clamshell dredges were developed.

By the 1860's, it was apparent to pioneers that a secure future lay only in cooperation, sufficient capitalization and proper coordination of a system of levees to avoid weak links.
Reclamation was taken up by teams of investors pooling funds together to buy property and reclaim it. The Tide Lands Reclamation Company was the most successful during the early reclamation period. Its president, George D. Roberts, became the most successful land agent in the history of the West. The company was established by San Francisco and Oakland investors in 1869 "to buy, sell, cultivate, dike, ditch, drain, reclaim, and improve tide and other lands in California."(Sucheng Chan, <u>This Bitter Sweet Soil,</u> 1986.) The corporation was capitalized at $12,000,000 issuing 120,000 shares at $100 per share.

Roberts brought tracts in his own name and through "dummy entrants" - men he paid to make entries at the land office in their own names. Later, the men sold or assigned title of their parcels to Roberts. Eventually, Roberts went bankrupt and David Bixler and Gen. Thomas H. Williams bought out the company in 1879. Other investors and developers included M.C. Fisher, James Ben Ali Haggin, Lloyd Tevis, and Ross C. Sargent.

The big land reclamation companies were a "mixed blessing." They "hogged" land; however, they also had enough money to build proper levees. When Roberts teamed up with Gen. Williams to reclaim in 1877, they hired three thousand Chinese laborers to build levees with the help of gang-plows and eighty-two horse-drawn Fresno scrapers. When the General rebuilt almost fifty miles of Union Island's ramparts, he paid a thousand Chinese laborers fifteen cents per cubic yard of dirt to build the levees. (Richard Dillon, <u>Delta Country</u>, 1982.)

b. <u>Chinese Laborers and Levee Building.</u> Most likely, without the Chinese, the Delta would have taken decades longer to develop into one of the richest agricultural areas in the world. Chinese laborers were employed to build levees before the 1880's. A document published by the Tide Lands Reclamation Company stated that Chinese were hired to build the first levees on the tracts in Rio Vista Township in Solano County, Twitchell Island, Brannan Island and parts of Roberts Island.

The levee builders worked long days rising at 5:00 a.m. and working until 6:00 p.m. The laborers worked in waist-deep muck under very unhealthy conditions. Many workers caught chills, pneumonia and malaria. Aside from accidents and disease, the Chinese laborers were also exposed to danger during heavy floods because they were ordered to pile sandbags around the inside base of the levees to strengthen them.

Most of the Delta islands and inland tracts already had low natural levees. Therefore, planks two feet wide were placed between a "borrow pit" and the natural levee; these boards formed a gently upward sloping plankway, supported at short intervals by pilings sunk into the mucky ground. Chinese laborers dug dirt from the borrow pit, shoveled it into wheelbarrows and slowly wheeled the barrows up the plank-way, dumping the fill on top of the natural levee.

Two kinds of fill were used to build the levees: peat and clay. The Chinese preferred to work with peat because it was much lighter than clay. However, the laborers were only paid 7.5 cents per cubic yard of peat, but were paid 13.5 cents for each cubic yard of clay. Landowners preferred that clay be used as fill because it could be packed more tightly. Also, peat had two contradictory tendencies: when peat was soaked with water, the weight of the water would pull the peat blocks down, causing the levee to sink as much as six feet per year; on the other hand, due to its buoyancy, it was impossible to pack the peat tightly.

The Chinese made special tule shoes to outfit the horses used to work on reclamation projects. The shoes were large ski-like woven mats of tule attached to the horses' hoofs to prevent them from sinking too deeply into the mud. Occasionally a horse would get stuck in the mud and could not be extricated.

Most landowners obtained their levee builders through Chinese labor contractors. A head contractor initially bargained for the job and then hired a subcontractor to supervise the actual work alongside the men. Both the head contractor and the subcontractor deducted commissions from the laborers' wages. Because most of the labor contractors were merchants, their chief source of income was not the commission they received but the profits they made by provisioning them. "It was very seldom that they made anything at all on the contract per acre; but they always stipulated that they shall have the privilege of supplying the Chinese and they made a profit in their stores." (Sucheng Chan, <u>This Bitter Sweet Soil,</u> 1986.)

George D. Roberts estimated that he and his company had partially reclaimed 30,000 to 40,000 acres using Chinese laborers. In 1876 he had three or four thousand employed under contract. Roberts would approach the Chinese labor contractors requesting a contract for a certain number of miles of levee. Roberts paid the workers ten to fifteen cents per cubic yard, as was the custom for this type of work. The work was measured after it was completed and then the laborers would receive their pay. Roberts reported that Chinese labor cost $6 to $7 for each acre of land reclaimed.

c. <u>Reclamation Period From 1880 to Early 1900's.</u> The introduction of heavy equipment in the Delta, like the clamshell dredge, made it possible to reclaim the central peat islands. By 1879, the clamshell dredge had replaced the Chinese "wheelbarrow gangs." The dredge was a barge outfitted with a long boom with two claw-like buckets attached to its end. The giant buckets scooped earth out of the low-lying areas or the riverbeds and the boom swung the buckets over to the levee to dump the fill. The dredge could move the mud for only five cents per cubic yard and at a much quicker pace than hand labor. (Hal Schell, Dawdling on the Delta, 1979.) At first, most of the work performed by the dredge was for large land companies due to the high cost of hiring the new equipment. Land developer Gen. Henry Naglee realized in 1878 that reclamation was too great a task for local jurisdictions so he petitioned the State legislature for assistance. With State and federal support, the 30,000 acres reclaimed in 1878 jumped to 323,000 in 1910. The amount of acreage reclaimed peaked at 490,000 by World War II.

4. The Delta's First Reclamation Districts.

In 1861, the State created a three-person Board of Reclamation Commissioners with authority to form reclamation districts if one-third of the landowners in the area agreed. One dollar per acre was allocated from the State's swamp land funds to pay for surveys and reclamation works. Later, reclamation districts were given taxing and bonding powers to enable them to raise more revenue; reclamation proved to be far more expensive than anyone had envisioned.

The Board of Reclamation Commissioners accomplished little. Many landowners that would not benefit from the building of levees, drains, dikes and ditches refused to be taxed by their neighbors who would. In 1868, the Board was dissolved and responsibility for reclamation was turned over to each county's board of supervisors. Counties could then authorize the formation of reclamation districts upon petition by one-half the landowners in the area. (Richard Dillon, Delta Country, 1982.)

CHAPTER II: MODERN DELTA LEVEES

1. Flood Control. (The Reclamation Board, 1991).

a. Flood Control Projects. Historically, the Central Valley flooded in years when there was heavy snow pack and/or heavy rainfall. The capacity of the river channels was adversely impacted by hydraulic mining in the late 1800's, which washed billions of tons of silt, sand, and gravel downstream until outlawed in 1884. Private development resulted in a haphazard scheme of property protection until the turn of the century when organized flood control became predominant. Several regional plans were developed and in 1911, the Debris Commission (created by Congress in 1893) put forth a plan for controlling the Sacramento River through leveed river channels, weirs, and by-passes. The Reclamation Board was created to carry out the Plan and Congress adopted the Plan in 1917. Early features included Knights-Landing outfall gates (1915), Sacramento Weir, and the Yolo Bypass (1916).

Flood control in the Central Valley is managed jointly by the State, through the Reclamation Board, and by the federal government, through the Corps of Engineers. The Reclamation Board was created by the Legislature in 1911 to carry out a comprehensive flood control plan for the Sacramento and San Joaquin Rivers, covering 1.7 million acres in 14 counties. No reclamation project of any kind may be started or carried out on or near the rivers until the Board has approved plans. The Board's efforts focus on controlling floodwater; reducing flood damage; protecting land from floodwater erosion that would affect project levees; and controlling encroachments into floodplains and onto flood control works, such as levees, channels, and pumping plants.

The Board uses both structural and nonstructural measures to prevent flood damage. Structural facilities include: (1) reservoirs to store flood water for later release; (2) levees to contain floodflows within a defined area; (3) bypasses to carry floodwaters which stream channels can't hold; and (4) channel improvements to enable a stream to carry higher flows while maintaining the same water level. As the State's share of projects, the Board provides land, easements, rights of way, and relocations. When a project is completed, the Board accepts responsibility for the project and usually turns it over to a local agency (reclamation district) to operate and maintain.

One aspect of flood plain management involves limiting flood-prone lands to uses that can be flooded with little harm. Local governments are responsible for controlling land use.

b. Flood Insurance Programs. Flood insurance is administered by the Federal Emergency Management Agency (FEMA). The program allows property owners to purchase flood insurance. The National Flood Insurance Program is based on an agreement between local communities and the federal government. The agreement states that if a community will implement measures to reduce future flood risks to new construction in Special Flood Hazard Areas (SFHA), the federal government will make subsidized flood insurance available in the community. The SFHAs are areas in the 100 year flood plain boundary, based on the existing conditions in the community. (NOTE: a 100 year flood is a flood level with a one percent chance of being equaled or exceeded in any given year).

The latest FEMA standard requires levees protecting residential structures to have at least three feet of freeboard above the 100 year flood elevation. If homes are in the flood plain, they may have to purchase flood insurance and may face restrictions on remodeling and additions. New development may not be able to be built unless building pads are elevated above the 100 year flood elevation. In addition, for areas of existing development, landowners may have to pay to raise the flood control levee (Stockton Record, 10/5/93).

Under State and federal law, Counties have responsibilities to manage flood plains, and to ensure that development authorized in a flood plain is suitably designed to withstand flooding or will not affect the capacity of the flood plain to carry flood waters, which would affect downstream areas. Development, which includes hard-surfaced areas, including roofs, parking lots, sidewalks, etc., will transport runoff from rain downstream more quickly. Undeveloped areas allow rainwater to soak into the earth, replenishing groundwater levels, and slow the movement of water into waterways. The Department of Water Resources is the State Agency that is responsible for the coordination and administration of the National Insurance program.

Counties establish operating elevations for levees based on current and historic levee elevations and the impact of each levee on base flood elevations (BFE) utilizing National Flood Insurance Program criteria (Sacramento County Floodplain Management Ordinance Companion Document, 8/9/93). The areas of special flood hazard are identified on FEMA maps.

As an example, Sacramento County requires a permit for all activities within federally designated special flood hazard areas prior to any new construction. The County Flood Plain Management ordinance creates a Floodplain Management Permit for this purpose. FEMA does not require a paper permit, but the County must review the impact of all development prior to approval of the development. Thus, County review of improvement plans and building permits provides the necessary review regarding flood plain impacts. Some activities are exempt from review because they are excluded from the definition of "development" including: normal farming activities; landscape maintenance; parking and storage of vehicles; levee maintenance; placing fill on a levee where the operating elevation of the levee is not restricted or regulated by federal, State or county laws, ordinance, or regulations; and other development the Flood Plain Administrator determines to have an insignificant impact on flood elevations.

2. <u>Project Levees.</u>

Project levees (see Figure 2), about 15% of the 1,100 miles of Delta levees, are part of federal flood control projects. Project levee systems were built through a partnership between the federal and local partner with the federal government engineering the levees and constructing the levees on lands providing by the local partner. The local partner is the California State Reclamation Board. Local reclamation districts carry out maintenance to federal standards with oversight from the State Reclamation Board. The Corps of Engineers designed the project levees to provide protection based on the individual site characteristics and site specific sampling, thus there is no one universal design (height, width of crown, slope of sides) for project levees.

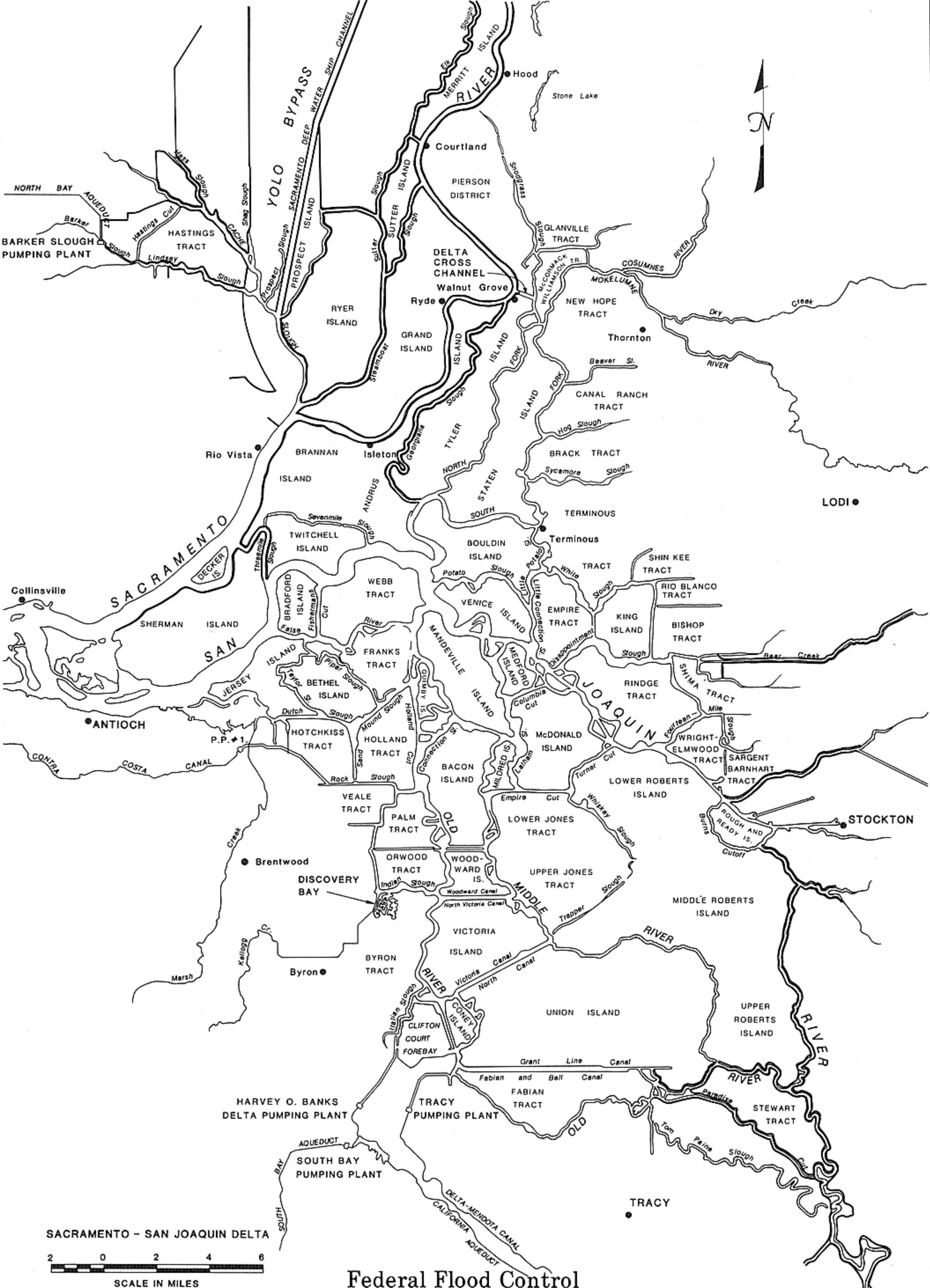
3. <u>Direct Agreement Levees.</u>

Direct agreement levees (see Figure 3) have been constructed as part of Corps of Engineers navigation projects or were rebuilt by the federal government after a flood. Direct agreement levees comprise about 10% of Delta levees. The local partner carries out maintenance of the levees; the Corps budgets maintenance funding for replacement of riprap displaced by commercial ships using the channels.

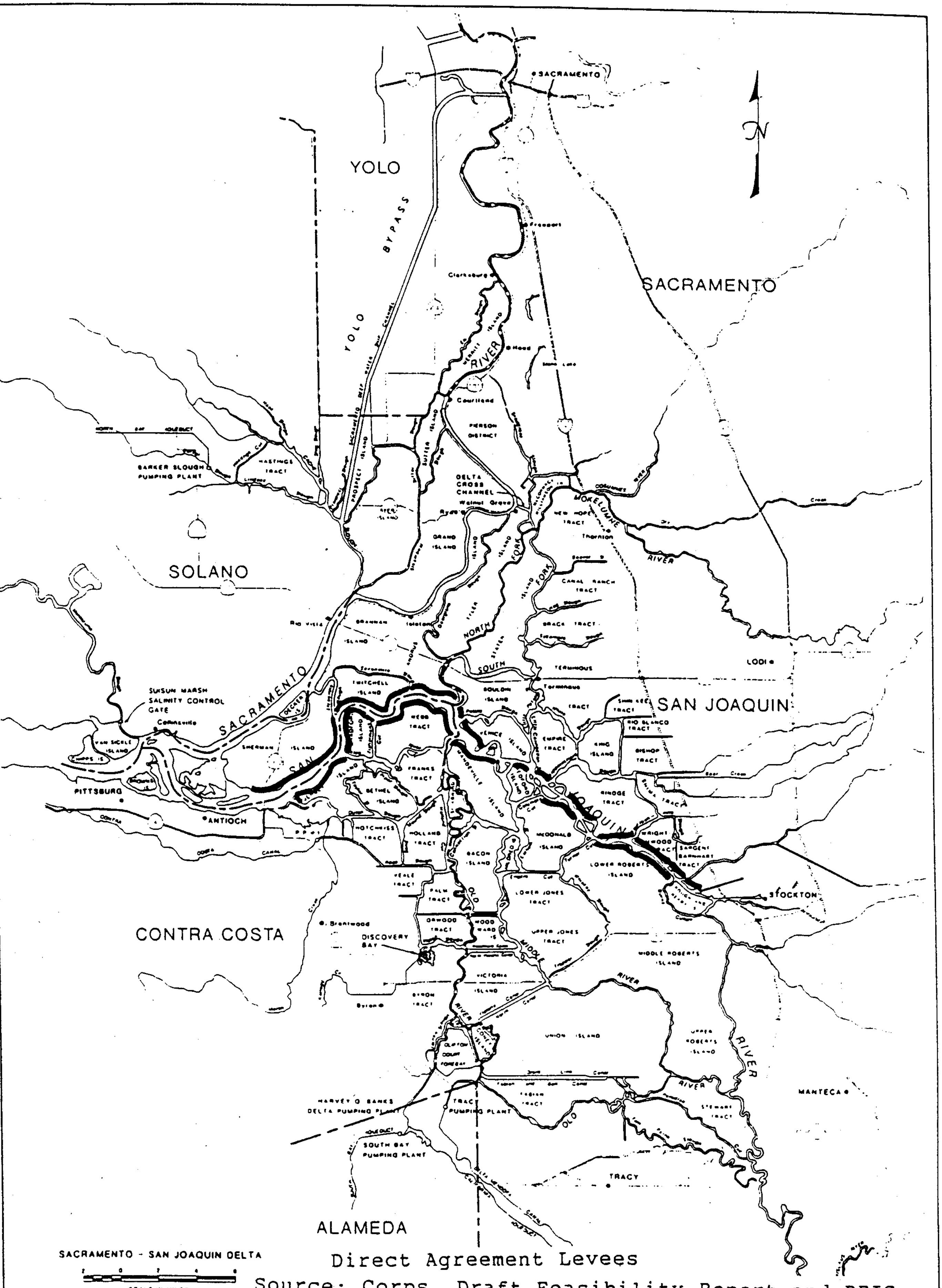
4. <u>Non-Project Levees.</u>

Non-project levees (see Figure 4) are levees built and maintained by the reclamation districts upon easements across the lands within the district. Delta levees (DFG, Draft Master Environmental Assessment, 1993) are built on and of locally available peats and silts, except in the peripheral areas where sandy silts are more common or along the main channels of the Sacramento and San Joaquin Rivers where river sands are available. Most have been built up over the years with material from nearby channels, by the use of side-draft, long-boom clamshell dredges. Problems of levee instability exist throughout the Delta, but are most critical in deep peat areas of the central and western Delta. Many private levees are in poor condition, due to construction materials, original design, and age. Most non-project levees have been greatly improved through the SB 34 program, overcoming historic problems of inadequate freeboard and levee sections, subsiding peat foundations, marginal stability, seepage from rodent activity or other causes, inadequate maintenance, or a combination of these deficiencies.

Non-project levees were not built to any specific standard or cross section. Many districts used the 1955 floods as a benchmark for providing appropriate protection.



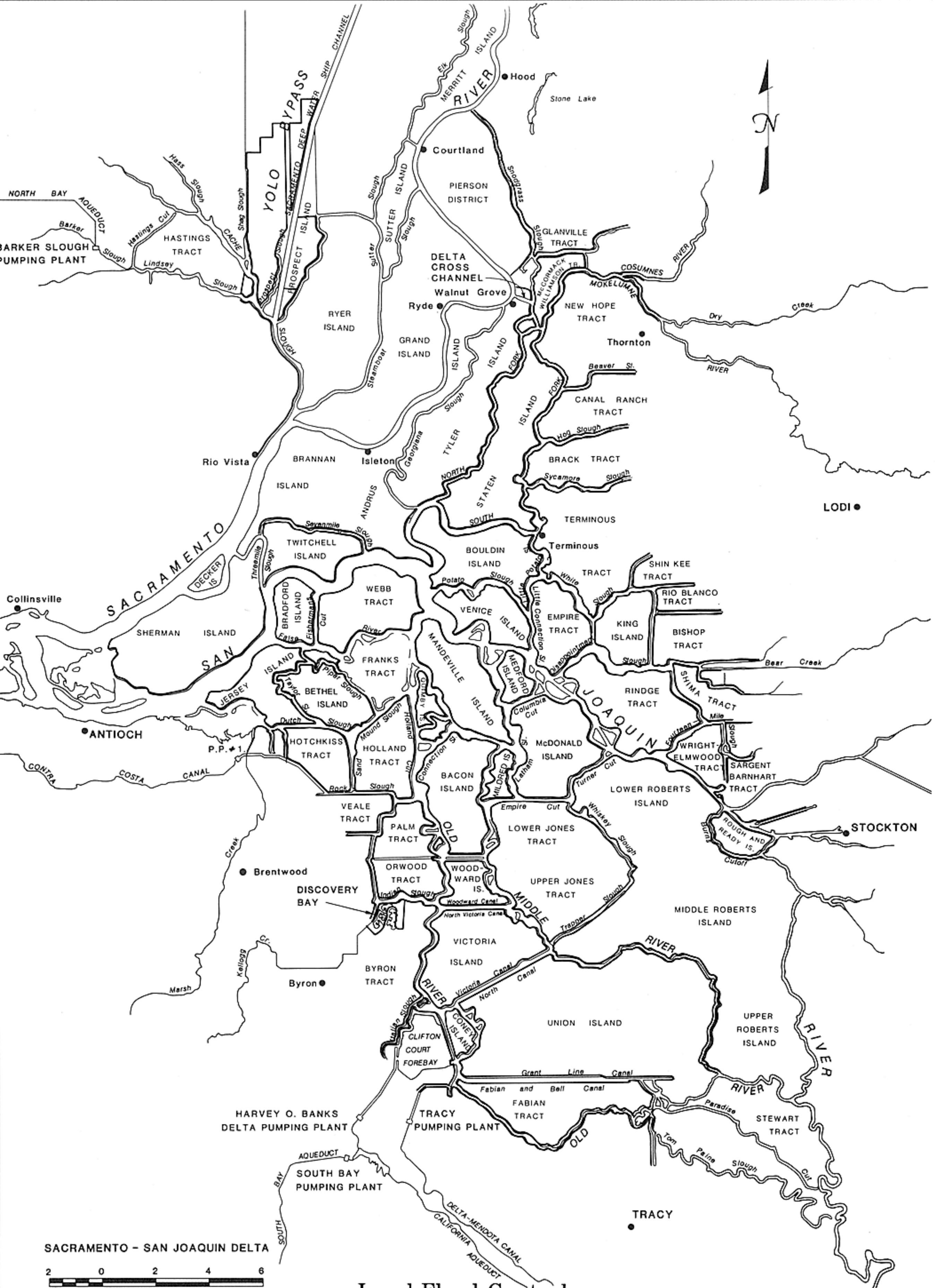
Federal Flood Control Project Levees



Direct Agreement Levees

Source: Corps, Draft Feasibility Report and DEIS: Sacramento-San Joaquin Delta, 1982.

Figure 3



Local Flood Control Nonproject Levees

CHAPTER III: MAINTENANCE OF LEVEES: VEGETATION

Levee maintenance falls into two general categories: maintenance of vegetation and maintenance of the physical structure (see Chapter IV). Maintenance of vegetation on the levees has been a controversial issue. Many want vegetation preserved for habitat and aesthetic purposes; others, particularly entities that fund construction and maintenance of levees, and directly suffer the consequences of failures, want vegetation on levees maintained in a way that maximizes ease of access to inspect and repair levees. Historically, maintenance of non-project levees was left to the discretion of the reclamation districts. However, in light of the cumulative adverse impacts to Delta habitat due to systematic removal of vegetation, and due to the impacts associated with periodic construction-maintenance projects on levees, State and federal wildlife management agencies responsible for regulating the environment have required districts to modify their approach to maintenance of levees.

Levees were built inland of natural shorelines, using material from the edges of islands for construction. This pattern of construction left remnant tule berms, or islands, in waterways, and often created a waterside berm or natural shelf. Both of these areas supported valuable riparian vegetation and provided habitat for Delta flora and fauna. Most of these vegetated areas have been eroded away by flood waters, tidal currents, and waves caused by wind and boats.

1. <u>Non-Project Levees.</u>

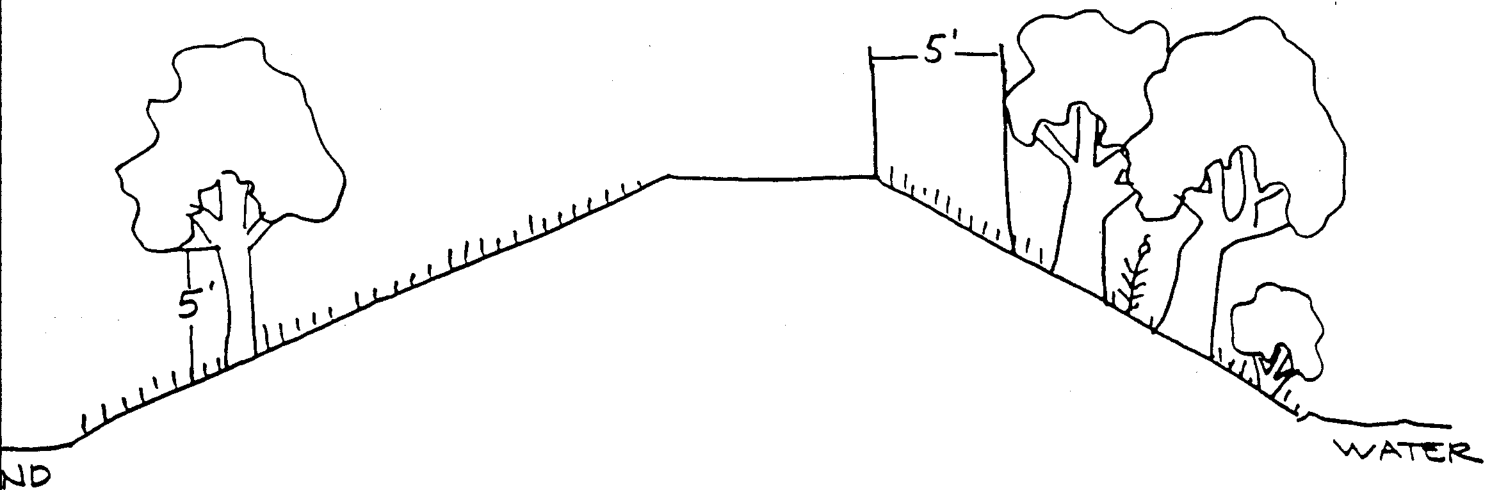
To provide direction for non-project levee maintenance, in the 1960's the Department of Water Resources (DWR) prepared guidelines, which recommended removal of most vegetation. The guidelines stated:

- Clear levees of all brush, trees, encroachments, and other obstructions;
- Shape levee crowns to provide uniform drainage; and
- Shape levee slopes to be uniform in shape and slope, without mounds, holes, or other irregularities.

In 1975, DWR's Bulletin 192 (Plan for Improvement of Delta Levees) presented a new levee vegetation program that allowed trees, shrubs, and grasses on the water side of levees between the top of riprap (1.5 feet above mean high water level) and the crown. Bulletin 192 was never adopted by federal agencies. Currently, DWR has developed draft vegetation management guidelines (see Exhibit 5) for non-project levees that allow limited vegetation retention on specific areas of the levee, depending on site-specific conditions and the recommendation of the supervising engineer. Approval of the guidelines by appropriate State and federal agencies is pending. These proposed guidelines state:

* Waterside Slope: All vegetation, except grass, cleared from top five feet of the levee slope. Encourage native grasses. Naturally growing vegetation below the 5' area should be pruned or removed only as needed to insure levee safety and inspectability. Large trees with extensive root systems are discouraged.

Proposed Vegetation Management Guidelines
for Local, Nonproject Delta Levees



LAND

Keep slope clear of vegetation.
Grasses encouraged, preferably native.
Mature trees may be retained.
Limbs trimmed up five feet from ground.

WATER

Keep upper five feet clear of vegetation.
Grasses encouraged, preferably native.

Source: DWR, Memo dated January 10, 1994.

Figure 5

* Landside Slope: Clear all vegetation from entire landside levee slope of levee and from a ten foot wide strip along the levee toe, except: (1) existing, individual mature trees with limbs trimmed up five feet from the ground, and (2) grasses, preferably native, to prevent erosion.

2. Project Levees. Federal regulations (CFR Ch.11, Section 208.10 Local Flood Protection Works) adopted in 1987, apply to structures and facilities constructed by the United States for local flood protection and managed by a responsible local agency. Under these regulations, levees shall be maintained as follows:

* Promote growth of sod.

* Exterminate burrowing animals.

* Mow grasses and weeds.

* Remove wild growth.

* Remove drift deposits.

* Retard bank erosion by planting willows or other suitable growth on areas riverward of levees.

* Inspect prior to the beginning of flood season and immediately following each major high water period and otherwise at intervals not exceeding 90 days.

* Inspect for: (a) unusual settlement, sloughing, caving on land or river side; (b) seepage, saturated areas or sand boils; (c) drainage systems and pressure relief wells in good form; (d) drains through levees in good condition; (e) displacement or removal of revetment work or riprap; (f) burning of grass or weeds in inappropriate season which will retard or destroy growth of sod; (g) maintain access roads; (h) gates in good condition; (i) crown shaped to drain and crown roadway is maintained; (j) no unauthorized grazing or vehicular traffic on levees; and (k) encroachments which might endanger the levee or emergency work on the levee.

* During flood periods, levees shall be patrolled continuously to locate possible sand boils or unusual wetness of the landward slope and to be certain there is no indication of slides or sloughing; no wave wash or scouring; no low reaches which may be overtopped or other dangerous conditions.

More specific guidelines for project levees are set out in "Interim Guide for Vegetation on Flood Control Levees Under Reclamation Board Authority", adopted September 16, 1988. These guidelines state:

Levee Slopes:

* Trees not permitted on standard levee slopes (a standard levee has width at the design levee elevation less than 30 feet).

Note: "Design levee elevation" is the levee height required to provide protection from the design flood. It is the theoretical minimum levee crown elevation, and is calculated by adding the design freeboard to the design flood elevation.

* On oversized levees (an oversized levee has a width at the design levee elevation of 30 feet or more and slopes that conform to the levee slope definition), trees permitted on unrevetted levees slopes and on levee slopes above revetment.

* On oversized levees, trees must be spaced to allow visibility of levee slope and toe from the crown road.

* On oversized levees, trees must be pruned five feet above ground.

* Trees adjacent to levee toe or 10 foot maintenance zone, shall be pruned to allow for unimpaired passage and operation of maintenance equipment.

* On oversized levees, trees should not exceed 50 feet in height. If taller, prune, top, or remove unless little or no threat to levee safety.

* On water side of oversized levees, trees not recommended within the high water range (may interfere with flood fight, such as placement of wavewash panels or protective plastic).

* No shrubs on levee slopes.

* Sod, grasses and nonwoody ground covers (12 inches or less) encouraged on slopes of all levees.

* Livestock grazing on levee slopes should be controlled to prevent overgrazing and erosion resulting from animal trails.

Levee Crown:

* No vegetation which interferes with maintenance and inspection activities.

Levee Toe:

* Within ten feet of levee toe, ground cover only.

Berms (relatively level area between levee toe and riverbank, usually no more than 15 to 20 feet wide in the Delta):

* Native and naturally occurring vegetation is allowed, discourage invasive plants and exotic species.

Revetment (riprap):

* Vegetation may be allowed within revetments unless it becomes a threat to the integrity of the revetment. Vegetation may be thinned, pruned, topped, removed or stabilized to correct any unsafe condition.

Orchards Adjacent to Levees:

* No trees planted within 25 feet of levee toe.

* No disposal of trees or cuttings in floodway or on levee slope, toe, or crown.

3. <u>Levees as Habitat.</u>

Riparian vegetation associated with levees is a critical habitat in the Delta on its own and because it makes other habitats more useful by providing cover. Riparian vegetation plays a key role in sustaining a great variety and density of migratory and resident fish and wildlife.

A new program with great opportunities for habitat enhancement is the re-creation of waterside berms at the levee toe. By placing a narrow band of riprap parallel to the base of the levee, lining the area between the toe and the new riprap with an impermeable material and then filling that area with dredged spoils, a new area of riparian habitat is created. This experiment has been successfully implemented on Staten Island along one-half mile of levee. Over 40 species of plants have been documented; the area is now used by many small mammals (Stockton Record, 2/10/94).

Levee maintenance through vegetation removal directly affects the amount and type of plant communities that persist on levees. Most Delta levees have been maintained for more than 50 years. Consequently much of the vegetation seen on levees today is represented by opportunistic weedy and often non-native species that thrive in disturbed soil conditions, such as after burning, mowing or discing. These plants are called "ruderal" and include wild radish, nettle, Bermuda grass, milk thistle, and giant bamboo. While animals will travel through or use this habitat for protection or feeding at some time during the year, it is not desirable habitat for breeding or long time residence.

If levee vegetation is not maintained annually, then other plant species may become established forming a more shrub/scrub riparian habitat community including willow, blackberries, alder, and a variety of herbaceous and woody vegetation. Protected plant species, such as elderberry, may be found in these areas. Shrub-scrub is preferred breeding and feeding habitat for migratory songbirds, pheasant, quail, muskrat, beaver, and various reptiles and amphibians. These are the most common habitat types affected by levee maintenance. Removal of these habitat types through maintenance or rehabilitation is considered a net long-term loss and must be mitigated in-kind under the SB 34 program. (See Chapter V, section 3)

Maintenance that has been deferred for long periods of time usually results in development of riparian forest habitat on levees. This plant community habitat includes broad-leafed deciduous vegetation 20 feet or more in height. Typical plant species found in this community include cottonwood, black willow, black walnut, alder, valley oak, and sycamore. Healthy riparian forest also supports understory plants. Removal of riparian forest for levee maintenance or rehabilitation is considered a net long-term loss of habitat, which must be mitigated under the SB 34 program.

Reclamation districts that perform levee maintenance on an annual basis usually do not have problems with sensitive species. Districts that have less frequent maintenance schedules tend to allow two or more years to pass between maintenance cycles thereby permitting development of shrubby vegetation. Sensitive species that may become established under such a maintenance cycle include elderberry bush (host to the valley elderberry longhorn beetle), the giant garter snake, California hibiscus, Delta tule pea and others. Riparian forest is utilized by Swainson's hawks for nest building and perching.

Once significant habitat areas and endangered species are identified on a site, the landowner must consult with appropriate state and federal agencies prior to vegetation removal.

If shrub-scrub or riparian forest habitat occurs at the water's edge, it is classified as shaded riverine aquatic (SRA) habitat by the U.S. Fish and Wildlife Service. SRA provides significant benefits for aquatic organisms, especially fish that find protection, food and shade under and among the vegetation. The benefits of SRA are increased on narrow waterways where SRA serves to cool the waterway and provide a significant source of detritus. SRA habitat is of special concern to both FWS and DFG and its removal as part of a reclamation district maintenance and rehabilitation is discouraged. This means levee maintenance may be directed to the land side of the levee and waterside maintenance "discouraged" (for example, proposed renovation of New Hope Tract levee; widening of levee for Highway 160 between Rio Vista Bridge and Antioch Bridge).

Avoidance is the first priority, if not possible, mitigation on-site, such as through creation of low water-side berms or through use of alternative revetments, which would allow revegetation, is the next choice. Finally, if avoidance or mitigation on site is not feasible, off-site mitigation may be provided. DFG is responsible for developing a mitigation guidebook for use by reclamation districts in the SB 34 program, which will include use of mitigation banks. Adoption of a delta-wide mitigation program, rather than island by island, would likely result in reduced administration costs.

CHAPTER IV: LEVEE MAINTENANCE AND UPGRADES: PHYSICAL

The vast majorities of Delta levees were built and are maintained by adjacent landowners. As each district independently built its levees, there were no uniform standards for height, crown width, or slopes. The Department of Water Resources (DWR) and reclamation district engineers worked with districts to try to provide adequate protection for district lands, but due to circumstances, there has been a wide disparity. Due to unique soils, geology, and other factors, DWR stresses the need for site specific geotechnical recommendations and specifications for each levee. While standards for flood protection can be defined for a region, there is <u>not</u> one universal levee design.

1. <u>Delta Flood Hazard Mitigation Plan.</u>

The State's Delta Flood Hazard Mitigation Plan (HMP) first adopted after the 1982-83 flood, describes the State's plan to meet Federal Emergency Management Agency Public Law 93-228, section 406, hazard mitigation requirements. Included in the plan was the local agency minimum levee standard for non-project levees. The plan was updated and submitted to FEMA after the 1986 flood. FEMA was not satisfied with the district's progress to meet minimum standards. Districts wishing to receive federal disaster assistance funds from the 1986 disaster and districts wishing to remain eligible for funding for future federal disaster assistance were required to submit to FEMA five-year workplans for achieving the minimum standards. The HMP levee rehabilitation standards are: (1) one foot of freeboard above the 100 year flood frequency elevations as determined by the Corps of Engineers; (2) minimum crown width of 16 feet; (3) waterside slope of 1.5 to 1, with revetment where erosion is a problem, (4) landside slope at least 2 to 1 with flatter slopes in the lower portion of the levee where soil stability and seepage have been problems; and (5) all-weather access roads. The HMP standard is considered a short term mitigation measure and may not be adequate if a levee has a poor foundation condition. The HMP standard is substantially less than the FEMA NFIP standard that is designed to protect urban development.

In addition, the HMP outlines maintenance actions needed by districts to correct maintenance deficiencies:

* control encroachments on levees.

* exterminate burrowing rodents and fill their burrows.

* shape levee crowns for proper drainage.

* repair slipouts, erosion, and subsidence.

* clean drains and toe ditches.

* repair revetment (riprap).

* repair and shape patrol and access roads.

* control weight and speed of vehicles using roads.

* cut, remove, or trim vegetation such as weeds, brush and trees to the extent necessary to maintain a safe levee.

* remove debris and litter from levees and berms.

* locate and inspect pipes and conduits through levees.

* repair and maintain gates necessary to control vehicular traffic on levees.

* conduct subsurface surveys to determine weaknesses within levees.

A letter dated March 10, 1992 was sent from FEMA to the State outlining the status of the districts' compliance to meeting the short term standards of the HMP, based on federal-State inspections after the September 1991 deadline. At that time, FEMA determined that only four districts <u>fully</u> complied with HMP standards. Those districts were: RD 2037, Rindge Tract; RD 563, Tyler Island; RD 2089 Stark Tract; and RD 1002, Glanville.

The main reason for non-compliance cited was lack of all-weather roads atop the levees. Other reasons included blocked levee crown access, low levee crown elevations, and unstable foundation material that delayed completion of back-filling subsided areas. Thirty-nine reclamation districts in the Primary Zone did not fully comply with the HMP standards. Non-compliance could mean loss of future disaster assistance from FEMA or possible requirements to pay back disaster assistance from past disasters. FEMA and State disaster assistance staff have been working on an agreement allowing districts to apply for time extensions to complete all-weather access roads or other tasks necessary to achieve full compliance to the minimum levee standards. DWR stresses the importance of both water side and land side berms to provide long-term levee stability. In addition, these berms provide opportunities for restoration of riparian vegetation on the water side, and upland habitat including riparian forest on the land side.

2. <u>Materials for Levee Repair.</u>

The first levees were built from soils directly adjacent to natural high areas along channels. In many areas, these soils were peat--light, subject to wind erosion and decomposition. The light soils were bolstered with elements such as logs, and brush, which were stronger, but still ineffective against flood waters.

"Modern" levees were constructed from deeper, higher percentage mineral soils scooped from shallow intertidal areas. By digging deeper, clamshell dredges were able to obtain more stable, more suitable material for levee construction.

Material for levee maintenance has traditionally been dredged from adjacent slough channels; and has predominantly been a combination of silt and sand. Sand is an appropriate levee repair material due to its weight and ability to stabilize. Dredging in Delta channels has been severely restricted in light of possible impacts to two endangered fish species: Delta smelt and winter-run Chinook salmon. Work is limited to "windows" of time where regulatory agencies believe imports to fish will be minimal.

Maintenance materials can also be scraped from higher areas within each island for use on adjacent levees or imported from quarries or other sites outside the Delta and barged in or trucked overland to the Delta.

In emergencies such as a levee break, a combination of materials has been used. The ends of a levee break are commonly riprapped immediately with imported rock to prevent further erosion. Then a combination of riprap and dredged material is used to repair the levee. Historically, remnants of islands created by clamshell excavation were used as source material for levee repair as well as material dredged from the channel bottom. Use of the channel islands for levee maintenance and repair is no longer allowed due to the extremely high value of the riparian habitat.

In June of 1972, the levee on Andrus Island failed. The Corps placed 834,000 cubic yards of rock and sand to repair the break. The repair work took 24 days to complete. Dewatering of the island took several months; farming resumed a year later (DWR, Bay Delta Oversight Council Delta Tour, 7/23/93).

Recent levee upgrading has incorporated dredged materials from other areas. In 1992, the Department of Water Resources performed levee upgrade on Twitchell Island using fine sand material dredged from the Clifton Court Forebay and from Suisun Slough. Repairs included placement of an 8-foot-high berm up to 120 feet wide and four miles long.

The Corps regularly carries out maintenance dredging of port districts' channels. The Stockton Deep Water Ship Channel was last dredged in 1992 and maintenance dredging is generally required about every 4 years. The next dredging is due in 1996. Recently, dredged material has been deposited on submerged islands in an attempt to recreate habitat. Sacramento Deep Water Ship Channel was last dredged in 1993 and generally requires maintenance dredging every 2 to 3 years. In addition, the channel is in the process of being deepened to 35 feet; new dredging should resume in June 1995. Suisun Bay Channel is dredged every year and it is part of the San Francisco Bay to Stockton (John F. Baldwin) Deep Water Ship Channel. Suisun Slough Channel is dredged about every 8 years. Dredging is due in 1999. New York Slough is dredged about every 4 years. Dredging is due in 1994.

Maintenance dredging of these Delta channels provides material that could be used to maintain or upgrade Delta levees. DWR is proposing to use dredged materials from New York Slough to upgrade levees on Jersey Island, under a carefully monitored project.

Dredging material from channel bottoms is regulated by several State and federal agencies. Additional concerns have been raised in light of possible adverse impacts to the Chinook salmon and the Delta smelt. Delta smelt spawn in the Delta between January and July, with most activity in April. Dredging during the spawning period can result in turbidity, which could result in smothering of eggs and larvae, reduced dissolved oxygen levels, and possible release of toxic pollutants into the surrounding waters. Winter-run Chinook salmon occur seasonally in the Delta during both adult and juvenile migrations. Adults migrate up the main stem of the Sacramento River from late November through mid-June, with highest numbers between January and March. Dredging may result in the direct loss of habitat, release of toxic pollutants into the water, reduce dissolved oxygen levels, and increase turbidity levels.

3. <u>Future Levee Maintenance Programs.</u>

A recent DWR study (Delta Levees Investigation Economic Inventory, 1993) of levee rehabilitation identified several levees as candidates for repair based on cost of rehabilitation and damageable resources. These include: Brannan-Andrus; Hotchkiss; Jones; Medford; Roberts-Drexler; Sherman; Shin Kee; Staten; Terminous; Twitchell; Tyler; and Victoria.

During 1994, the Corps of Engineers will be studying Jersey, Twitchell, and Webb Islands with DWR. The reconnaissance studies will look at flood control and environmental restoration on islands located along the Stockton Deep Water Ship Channel.

Due to difficulties of levee maintenance along the Sacramento Deep Water Ship Channel, the Corps of Engineers will prepare a reconnaissance study of Prospect Island with the Bureau of Reclamation; the levees may be removed and the area enhanced as a tidal wetland.

The Corps of Engineers has been evaluating the status of 295 miles of project levees on the Sacramento River south of Freeport and in the Yolo Bypass (Corps of Engineers, Draft: Sacramento River Flood Control System Evaluation, 1993). The draft report indicates that substantial sections of the project levees are susceptible to seepage, subsidence, and stability problems and do not provide the design levels of flood protection. The levees are required to provide a minimum three feet of freeboard to meet design requirements. After the 1986 floods, the design water surface was recalculated and it was determined that these levees no longer provided the required freeboard.

About 47 miles of reconstruction work would be required to meet project design requirements. About 18 additional miles of levees north of the Delta may need reconstruction work. About 6,000 people reside landward of the levees that need reconstruction; damageable property is estimated at $460 million. The draft report notes that although federal project levees have not failed in the lower Sacramento Area, problems are such that, without reconstruction, the federal project levees are likely to fail in the future at nineteen locations.

The cost to reconstruct all these levees would be $71.5 million. Based on economic analysis, only some of these areas are proposed for reconstruction. Economically justified work includes RD 349, Sutter Island; RD 999, Big Area; and RD 3, Grand Island, with costs of about $2.83 million.

4. Current Findings on Levee Maintenance. (Foott, Lessons from Levees, 1993).

DWR has been monitoring recent levee repair and upgrade projects. Levees on Sherman and Twitchell Islands exhibited major structural problems including cracking, sinkholes, piping, seepage, boils, and leakage.

At Sherman Island, large cracks were found on the landside levee slope. A berm was placed outside the levee toe to improve stability and to reduce lateral movement close to the levee crown. The levee crown was compacted to seal cracks and the crown height raised above expected design flood elevation. For two years, crown deformations have been minimal and no significant cracking has been observed.

Sinkholes occurred on the land side of the Sherman Island levee. The sinkholes were 6 to 10 feet in diameter and 6 feet or more deep and full of water. Tests around two major sinkholes indicated a "tear" in the peat foundation directly below the levee into which the overlying soil was being washed by seepage, creating the sinkholes. Cement-bentonite grout was pumped into the soil, filling the voids and holding the peat in place.

"Piping" occurred through the levee on Twitchell Island, probably related to animal burrows or permeable strata. A trench was cut along the top of the levee and backfilled with clayey soil to impede water flow, and fill was placed on the backslope of the levee to stabilize the area.

Creep of the levee backslope occurred on Sherman Island, at a location where fill was placed. The underlying peats responded to placement of fill by deforming laterally. The movements have been observed for over two years and continue at a slow but relatively steady rate totaling about 12 inches.

Twitchell Island had a very eroded levee built on 20 to 40 feet of very soft peat soil, with a narrow crown, a steep backslope and low crown elevation. The levee leaked badly at times of high water. To strengthen the levee, a berm was constructed on the land side of the levee between 60 and 120 feet wide, and 8 feet high. The berm was built up over time in layers three to four feet deep. The berm was designed to provide a stabilizing mass, consolidate and firm up the peats providing a widened base upon which the levee section could be improved.

Two methods were primarily used. The first method was to cut a trench along the top of the levee at the seepage location and backfilled with a clay material to reduce its permeability. The second method was to install drainage to collect the seepage and carry them to the levee toe.

Numerous areas of seepage and boils on the backslope of the levee occurred. A trench was cut along the top of the levee that was then backfilled with compacted clayey fill or with material mixed with bentonite. A drainage system was installed on the backslope to collect the seepage outflows.

CHAPTER V: LEVEE MAINTENANCE AND UPGRADES: FUNDING

Identification of long-term funding sources for Delta levees will be critical in 1997-98, the year before the current funding program is due to expire. Historically, the landowners on each island paid all costs of levee construction and maintenance. However, due to increased use of the Delta as a water transport system, as a regional recreational resource, as a transportation link, and its identification as critical habitat for several rare and endangered species of flora and fauna, the cost of maintaining levees needs to be distributed fairly through the user communities.

1. <u>Historic Maintenance of Non-Project Levees.</u>

Historically, the reclamation districts were responsible for all aspects of levee maintenance: development of levee height and cross-section, preparation of plans and cost estimates, taxing the land owners within the District to pay for the levee maintenance, and carrying out or contracting levee maintenance. Some Districts minimized costs by using member-owned equipment, member labor, on-site materials, minimal design and permitting costs, minimal environmental review, etc. Disparities between the amount of money spent on levee maintenance by different reclamation districts have been large.

Annually, reclamation districts set assessment rates needed to fund work for the upcoming year including materials, equipment, consultant costs and staff. The assessment is set by the Board of Trustees of each district, published in the paper, and bills sent to property owners. Funds collected are sent to the County assessor who holds the funds for the reclamation districts.

After the floods of the 1980's, the federal government required the State to adopt and implement the Delta Flood Hazard Mitigation Plan. Once reclamation districts reached those standards, if there was emergency damage, reclamation districts would be eligible for emergency funds.

To fund the program to upgrade levees to HMP standards, SB-34 was enacted in March 1988, and sunsets on January 1, 1999. The program includes funding of up to $6 million per year to reimburse up to 75% of maintenance costs, after the first $1,000 per mile is paid by reclamation districts. Progress has been slow, as for several years there was not full funding of the program; and regulatory problems have slowed or precluded issuance of permits. In 1989-90, districts paid $8.6 million and the State paid $5.3 million; in 90-91, districts paid $8.4 million and the State paid $2.3 million, and in 91-92, districts paid $10.7 million and the State paid $2.1 million.

For the period 1980 to 1985, $16 million total was spent on annual maintenance and rehabilitation of non-project levees; $10 million by reclamation districts; $6 million from early subventions program. In this same period, the federal government spent $67.4 million, the State spent $28.6 million and local entities spent $5.8 million for emergency work and flood disaster relief in the Delta (Sacramento-San Joaquin Delta Emergency Water Plan, Dec 1986).

2. <u>The Delta Levee Maintenance Subvention Program (Way Bill).</u>

The first subvention program was authorized under the Way Bill in 1973. The bill authorized 50% reimbursement for levee maintenance, with a total budget of $200,000 per year for five years. No funds were provided for 1979-1981. Under the program, 8 to 10 districts per year received funding. The program was administered by the Reclamation Board. The program was re-established in 1980 with 50% reimbursement and a budget of $1.5 million per year.

3. <u>SB 34: Delta Flood Protection Act.</u>

After the floods of the 1980's and expenditure of millions of state and federal dollars to reclaim flooded islands, SB 34 was approved. The legislation includes the Special Flood Control Projects and the Levee Subvention Program which authorizes 75% reimbursement, after the first $1,000 per mile of costs, and with a budget of up to $6 million per year. The overall budget for SB 34, is $12 million per year.

Levee maintenance to the HMP standards is partially funded under the SB 34 program. Of the funds set aside for levee maintenance of non-project levees; some of that amount has been earmarked for environmental studies and enhancement. The program has been hurt by overall underfunding in years of budget problems, conflicts in achieving the environmental mandate, increased scrutiny by regulatory agencies, increased costs to meet program environmental documentation requirements and increased administrative costs in order to comply with competitive bidding law.

Under the Special Flood Control Projects, $6 million a year is set aside for special studies and to upgrade levees on eight western islands and the communities of Thornton and Walnut Grove. Those islands include: High Priority: Sherman, Bethel and Hotchkiss; Medium Priority: Twitchell, Webb, and Jersey; and Low Priority: Bradford and Holland. To date, levees on Sherman, Bethel, Webb, Twitchell, Holland, Hotchkins and Bradford have been upgraded; Jersey Island and New Hope Tract (Thornton) levees are due to be upgraded in 1994.

4. <u>Emergency Levee Repairs.</u>

Emergency repairs (DFG, Draft Master Environmental Assessment, 1993) have historically been funded through federal and State emergency funds, with the costs ultimately falling on the taxpayers. In some cases, reclamation has cost much more than the <u>appraised</u> value of the land being reclaimed; appraised value does not include the value of Delta islands to the State and federal water projects or their value as upland habitat. Because of changing policies and increasing costs, continued financial support for restoration of flooded islands from federal programs is less certain. Big Break and Frank's Tract were flooded many years ago. Little Franks Tract and Mildred Island, both flooded in 1983, have not been reclaimed.

Many landowners believe the cost of emergency levee repairs could be minimized by State assistance in ongoing levee maintenance.

Following the levee failures of the 1980's, the Corps of Engineers determined that federal public Law 84-99 could no longer be used to justify repair or restoration of non-project levees in the Delta. FEMA has indicated that it may be unable to recommend federal financial assistance for restoring flooded islands under Public Law 93-288, unless in an emergency situation the public interest requires protection against salinity intrusion into aqueducts that furnish water supplies, or unless there is significant non-federal effort to improve Delta levees so that the frequency of future levee breaks are significantly reduced. The Corp reinstated PL-99 in 1987 and reclamation districts have been working to meet federal goals through implementation of the HMP.

5. Future Funding of Levee Maintenance.

Past plans have attempted to fully identify the beneficiaries of the Delta levees including:

a. Landowners: agricultural, commercial, residential, industrial, governmental, utilities, and railroads.

b. Recreational Users: pleasure boaters, water skiers, swimmers, picnickers, campers, fisherman, hunters, tourists, and naturalists.

c. Others: State Water Project, federal Central Valley Project, commercial fishing, fish and wildlife, Port of Stockton, Port of Sacramento, San Francisco-Bay Delta estuarine system, economy of region, state and nation, and Rough and Ready Naval Station (also mineral rights).

Clearly, Delta levees provide benefits that go to local residents, regional visitors, and statewide and national water projects, recreational, shipping, and local, statewide and international environmental interests. There has been no recent study identifying the value of Delta levees to the various parties, nor any study of how to capture funds associated with those values to be set aside for long-term levee maintenance.

There is no long-term commitment of federal funds for Delta levee maintenance despite the value of the levees in protecting the quality of water exported by the Central Valley project.

CHAPTER VI: REGULATORY PROCESS FOR MAINTENANCE, UPGRADES AND EMERGENCY REPAIR

1. Reclamation District Levee Work.

Reclamation districts are special districts created by the State which are self-regulating. They do not need permits from Counties for levee work; the districts certify the environmental documents required under the California Environmental Quality Act (CEQA) for levee work. Reclamation districts do need approvals from State and federal agencies for certain work.

Under CEQA, reclamation districts act as the lead agency for their own projects. A lead agency is responsible for preparation and adequacy of the environmental document for activities that may have a significant effect on the environment. CEQA designates certain activities as exempt from CEQA review. Under CEQA, adverse impacts to the environment may need to be mitigated. Department of Fish and Game is preparing guidelines for mitigation which may be required for levee maintenance or construction work.

DWR is not a regulatory agency, and the subventions program is a reimbursement not a regulatory program. For work to be funded under the State levee subventions program, the project description must conform to requirements set by DWR for delineation of location of work, time of work, details about the volume, type and source of materials to be placed, and the amount and type of vegetation to be removed during levee maintenance. Districts must also show fencing, gating and any other improvements to be located on the levee.

For work on lands where State Lands Commission (SLC) believes the State retains a property interest, or on ungranted tidelands and submerged lands owned by the State or the bed of navigable rivers, sloughs or lakes, the SLC must issue a lease to the district under Public Resources Code Section 6301. If the proposed work is for bank protection for an on-going agricultural land use, SLC may waive royalty charges. The lease does not resolve any property disputes that may exist, but allows necessary work to take place without delay. Leases for levee maintenance work can be issued for a five year period.

Generally, an entity proposing an activity adjacent to levees or streams along or near the banks or levees of the Sacramento River, San Joaquin River or in or adjacent to other Central Valley streams must obtain an encroachment permit from the Reclamation Board. Examples of the types of activities that require encroachment permits include changes in land use, construction, earthwork, or removal of vegetation. The Reclamation Board maintains jurisdiction over all federal Flood Control Project, or "project levees", from a point ten feet landward of the first levee toe to a point ten feet of the second levee, including all portions of the levees and the river bed. The Reclamation Board has jurisdiction over "non-project levees" if the proposed project could have an effect on nearby project levees. The Reclamation Board also controls "designated floodways" which includes all bypasses and weirs within the Delta.

For work within all waterways and work on the waterside of levees up to the levee crown, a Fish and Game agreement is required under Section 1600 of the California Fish and Game Code. While several districts have disputed this authority, districts have entered into agreements that do not waive any property rights. A fee of $111.00 is required for each agreement. Each agreement can be issued for five years. A separate permit is required for suction or vacuum dredging activities in any lake, stream, or river of the State. Suction dredging is usually associated with sand and gravel excavation activities, but can be used to obtain material for levee maintenance.

For dredging projects, the Central Valley Regional Water Quality Control Board now requires that current information on pollutants in materials to be dredged be identified. In addition, the San Francisco (Winter Island and areas west) and Central Valley (areas east of Winter Island) Regional Boards issue National Pollutant Discharge Elimination System (NPDES) permits under federal legislation. Dredging and levee modification may require NPDES permits. However, since the Corps of Engineers also permits dredging activities, the Regional Boards have the authority to either certify, or waive certification, that the Corps of Engineers dredging permit will not violate water quality standards. (Note: the boundary between the two Regional Water Quality Control Boards is the same as the boundary between the San Francisco and the Sacramento Corps of Engineers jurisdictions.)

Any proposal to perform earthwork within a State highway (160, 4, 12, 84, 113, 220) or freeway (5 and 80) right-of-way or easement must obtain an Encroachment Permit from the Department of Transportation (CalTrans).

Any work which includes purchasing material "mined" from an island, must have a plan prepared under the State Mining and Reclamation Act. This is a statewide requirement.

For work within navigable waterways, a Corps of Engineer's Section 10 of the Rivers and Harbors Act permit is required and to discharge dredged or fill materials in the waters of the United States requires a Section 404 of the Clean Water Act permit. Historically, the Corps has issued general permits that cover routine work. The last version of General Permit 14, which covered dredging for levee maintenance, repair of riprap, and other minor levee repair work has expired; a new version is under preparation with severely restricted dates for dredging based on critical times to protect Delta smelt and Chinook salmon migratory habits. Due to concerns about endangered species, the Corps of Engineers is in close consultation with other federal environmental agencies such as the Environmental Protection Agency, the National Marine Fisheries Service and the U.S. Fish and Wildlife Service.

Under State and federal endangered species acts, "taking" (meaning to kill or destroy) must be approved prior to any work. This requirement cannot be waived under an emergency.

2. <u>Emergency Levee Repair Work.</u>

Permits are required for emergency repair of levees. However, there is no clear procedure for declaration of a Delta emergency; no clear designation of which entity--local, state or federal--shall take the lead role in regulating emergency levee repair; and there is no emergency fund designated specifically for Delta levee repair. As discussed earlier, emergency repair work has cost millions of dollars and requires immediate attention to control immediate problems of levee breakage and to minimize the extent of levee damage. Emergency repair work requires specialized material (large amounts of riprap and other materials.) and specialized equipment (barges, cranes, dredges, and large pumps) which are not commonly found in reclamation district equipment inventory. The need for immediate levee control and repair work may also require the immediate attention of a large number of workers to apply plastic or sand bags, or other labor intensive work.

DWR has developed a one page emergency guide for the eight western islands. The guide identifies actions required by a reclamation district in case of an emergency, included are State and federal agency contacts. Other reclamation districts have developed emergency preparedness plans.

CHAPTER VII: IMPACTS ASSOCIATED WITH LEVEE FAILURE

When evaluating the need to retain existing levee systems, it is crucial to consider some of the adverse impacts on the region and the State if levees were lost. Several impacts are highlighted below. In addition, short-term and long-term flooding would severely impact and potentially eliminate agriculture and land-based recreation activities. Fortunately, there has been little loss of life in Delta floods. As the Delta population increases, the risk of loss of life during floods will also increase.

1. Water Quality in the Delta and for Exports. (Corps, 1982)

Maintenance of Delta water quality is of statewide and local importance. The Delta channels serve as sources of water for Delta agriculture and as conveyance of water exports through the southern Delta to serve other parts of the State. The Delta is subject to intrusion of salt water by tidal action from the San Francisco Bay. Salinity intrusion is controlled naturally through Delta outflow, and in low flow periods by release of waters from State and federal reservoirs. If a Delta island floods during low flow periods, the most likely source of water to enter the Delta to fill the island would be salt water from the Bay. If the island floods during low flow periods, additional water from reservoirs would have to be released, if available, and export pumping stopped or decreased to maintain water quality standards. Waters released from reservoirs to repel or mitigate salinity intrusion is water lost which could have otherwise been used for delivery to project customers or for wildlife habitat enhancements. During high flow periods, a levee break would have minimal impact on water quality.

An example is the 1972 Andrus-Brannan flood. The flooding occurred in a low flow period, June to August, and resulted in high salinity conditions during those months. About 294,000 acre feet of water was released from upstream reservoirs to reduce salinity intrusion into the Delta.

Long-term impacts associated with permanent loss of a levee include changes in the location of the mixing zone - the zone where saltwater from San Francisco Bay, and freshwater meet and mix.

2. Loss of Property.

Levee failures result in flooding with devastating losses of property. In 1982, a levee failed on McDonald Island. The levee failure occurred in August at 6 a.m. By 9:30 a.m. the water was rushing through a 300 foot wide gap at 30 to 40 knots. Flood waters inundated the 6,145 acre island. Crop damages were estimated at $5.3 million. Preliminary estimates for closing the levee and dewatering the island were set at $6.3 million (Corps of Engineers, 1992).

In 1980, about $50 million was spent for flood damages, levee repairs and emergency costs. On January 18, 1980, the levee on Webb Tract failed at 5 p.m. A 12 foot wide rupture widened to 850 feet. The 5,400 acre tract flooded up to 20 feet deep. On the same date, a saturated section of the levee on Holland Tract failed, and 4,400 acres were flooded. That break widened to 250 feet wide and 40 feet deep. On February 21, Dead Horse Tract levee failed. Floodfighting was required on Bacon, Venice, Bouldin, Medford, McDonald, and Veale Tracts.

On September 1980, a levee on Lower Jones Tract flooded 5,200 acres to a depth of 10 to 15 feet. The 80 foot wide breach widened to 275 wide and 55 feet deep. The railroad embankment between Upper Jones and Lower Jones failed on October 23, 1980.

On January 20, 1969, a Sherman Island levee failed. A crack widened within minutes to a gap 300 feet wide and 40 feet deep. Structures on the island were flooded to depths of 5 feet and were a complete loss as a result of wind and waves. The flooding displaced 200 residents and disrupted gas wells, State Highway 160, oil, and gas lines and high voltage power transmission lines. Total damages were estimated at $22 million (in 1981 dollars).

3. Loss of Habitat.

Delta levees protect important wildlife habitat for numerous species of waterfowl, shorebirds, and other terrestrial wildlife. Terrestrial habitats in the Delta support:

* about 20 species of mammals;
* 230 species of birds;
* 25 species of reptiles and amphibians; and
* 150 species of flowering plants.

If Delta islands were to flood, the terrestrial habitat would be replaced by open water habitat useful primarily for fish and other aquatic life. Land subsidence throughout most of the Primary Zone would result in flooded areas with deep water. These deep water areas would not have high phytoplankton production, and would thus be of lower value to the fisheries. The net result of flooding islands would be the loss of significant habitat for land-based species in exchange for marginal habitat for water-based species.

The Delta is an important area in the Pacific Coast flyway for migratory waterfowl and birds. Winter use of the Delta by waterfowl is currently high. This high level of use is associated with the rich food source associated with grain residues left after harvesting. Permanent flooding of Delta islands would eliminate these food sources and have a disruptive impact on use of the islands that are part of the Pacific flyway.

CHAPTER VIII: LEVEE FAILURE MECHANISMS

Levee failures continue to be one of the Delta's primary problems. Levee failures in the Delta are due to several factors, including: instability, overtopping, and seepage. When a levee fails, the beneficial use of the island and waterway are jeopardized as well as lives of people inhabiting the island. Major costs are also incurred to reinstate the levee and dewater the island.

1. <u>Failure Categories. (DWR, Delta levees, 1993)</u>

Failures can be identified principally by the major category of failure (stability, overtopping or subsurface seepage erosion), then more specifically by contributing factors (subsidence, cracks and fractures, encroachments, erosion, deformation, seepage, sink holes, rodent burrows, and poor foundation conditions). One characteristic that aggravates failures is the contribution of subsidence.

a. <u>Subsidence.</u> Subsidence is a significant factor in many of the central and western Delta levee failures, since it has caused many of the islands' interiors to lie substantially below sea level. Subsidence is due primarily to the loss of organic soil such as peat, a soil that contains more than 50 percent organic matter. Exposing peat to oxygen causes aerobic decomposition, a process whereby microbial organisms convert organic carbon solids to carbon dioxide and other gases. Activities, which raise the soil temperature and reduce soil moisture, greatly accelerate this process. This reaction occurs within the first few feet of soil and is referred to as shallow subsidence. Deep subsidence, which has little effect in the Delta when compared to shallow subsidence, is caused by groundwater withdrawal and a decline of natural gas pressure.

Land subsidence research for the Delta is continuing under a cooperative agreement between the United States Geological Survey and DWR. Currently the USGS is conducting a study on Twitchell Island to determine the rate at which the soil is losing carbon (carbon flux) under various land and water management practices. The working hypothesis of this research is that flooding and vegetative cover will cause the rate of oxidation to slow. Results of evaluating historical subsidence indicate that subsidence is slowing over time variability of subsidence rates are related to varying soil organic matter.

Continuing subsidence poses a major threat to the stability of the West Delta levees. Results of an analysis by the Corps of Engineers indicates that there is likely to be two to three times the number of levee failures as a result of subsidence during the next 30 years, compared to the last 30 years.

b. <u>Stability.</u> Factors that affect levee stability include size, shape, soil strength, deformability, and water pressure. For example, on Twitchell Island, high, narrow levees made of weak soils over deformable peat foundations were among some of the most unstable levees in the Delta.

Levee foundation materials in the Delta vary. They include clay, silt, and sand in the east Delta and peat with some alluvial clay, bay mud, sand, and silt deposits in the west Delta. In general, the inorganic materials provide adequate foundation conditions, but uncompressed peat has an extremely low density and is highly deformable. Water pressure against and within the levees, and the weight of the levee can cause this foundation material to compress and to displace laterally, resulting in subsidence and potential levee failure.

Differential foundation settlement may be another cause of stability failures, particularly where levees were built on peat that abuts old, historic river channels, or sloughs. The clay, silt, and sand-filled channels do not consolidate at the same rate as the surrounding peat. Cracks may develop in the levee above the old channel, encouraging subsurface seepage erosion called *piping*.

Levee failures are often preceded by a localized partial failure involving 200 to 1,000 linear feet of levee. Partial failure includes settlement of the levee and the formation of cracks and sinkholes in the landward levee slope. Unless repair is immediate, the condition may become worse until the levee fails completely.

c. Overtopping. Overtopping failure occurs when the levee crown is lower than the water level. The combination of high tides, wind, and high discharges into the Delta contribute to overtopping. While construction of upstream reservoirs since the middle 1940's has reduced the frequency of levee overtopping, overtopping remains a threat to the Delta, especially to islands of the North Delta.

On December 3, 1983, a section of levee on Bradford Island failed as a result of overtopping. Abnormally high tides coupled
with high river discharges and high winds produced a dangerous situation.

d. Subsurface Seepage Erosion. Water seeping through or beneath levees may result in critical conditions as the soil erodes through the levee, creating large voids (pipes). These voids continue to grow and work their way backwards from the seepage discharge point. If not properly controlled, levee failure may occur because the levee simply washes away from the inside out. The Thornton (New Hope) levee failure represents this type of failure and is characteristic of the sandy eastern Delta levees. Piping may be caused by any one of the following:

- burrowing rodents,
- loosely consolidated or sandy levee material,
- decaying tree roots,
- old pipes buried in the levee,
- settlement cracks,
- high water, or
- a narrow levee.

2. Failure Modes (DWR, Delta Levees, 1993).

To provide adequate protection for Delta islands, it is necessary to understand the characteristics and causes of levee failures. The failure modes can either be identified as continuous or transient in nature.

a. Cracks and Fractures. Cracks and fractures in levees are often a common sign of levee distress, especially on deep peat islands in the western Delta. The cracking phenomenon is caused by the highly deformable nature of the peat soils beneath and to the landside of levee embankments. Peat typically deforms when fill is placed on peat that has not previously been loaded. As the peat deforms and consolidates in response to the weight of the newly applied fill, it becomes less subject to deformation.

For example, on Twitchell Island, four feet of berm fill placed on virgin peat has settled to below the original ground elevation. Large settlements in the berm resulted in 6-inch-wide cracks, with almost a foot of vertical offset.

Another cause of cracking is lateral movements of the underlying peat, particularly beneath the levee's berms. These movements may be related to a lowering of the water table on the land side of the levee. Reports of cracking of the landside slope of levees after times of drought are not uncommon and probably are due to this cause. However, throughout the peat soil areas, natural subsidence and on-going agriculture will result in a lowering of the water table on the islands.

Once cracked, the levee fill material may tend to act as a series of adjacent blocks on a soft base, and relative movements (e.g., as a heavy block settles and heaves up a lighter adjacent block) can be expected. Additional loading could also trigger relative movements. Significant cracking may occur following periods of high tide or following placement of additional fill on the levee crown.

b. Encroachments. Encroachments may reduce the level of protection provided by the levee system and also make levee maintenance and improvements more difficult. The performance of levees, which are critical during periods of high water, can be compromised by structural encroachments. Structures (houses, walls, boat docks, etc.) covering the levee slope may hinder inspection of seepage, boils, rodent burrows, sinkholes, sloughs, or cracks.

The problem of encroachments can be seen most clearly on Bethel Island and Hotchkiss Tract in the Secondary Zone. Many homes were built on the levee with retaining walls as foundations against the levee slope before the enactment of building setback regulations. Bethel Island Municipal Improvement District adopted an ordinance in June 1989 that established setback regulations. Efforts to identify all the encroachments on these two islands have been completed. Encroachment control plans are currently under development.

c. Erosion. Prior to construction of the levees, the low natural levees were protected by vegetation along the channels. A balance of erosion and deposition maintained channel volume.

Erosion of Delta levees is caused by many sources. Natural sources include currents, tidal action, wind waves, and flood waters, rodent burrows, seepage forces, and vegetation. Other sources include wakes from vessels, including recreational boats; increased volume, elevation, and speed of waters drawn through the Delta into the two sets of pumps in the south Delta for the State Water Project (state) and the Central Valley Project (federal); unauthorized parking on the edge of berms; and creation of paths on the levee face by grazing animals or by humans.

A 1971 report on levee damage (Tetra Tech, Causes of Levee Damage in the Sacramento-San Joaquin Delta, 1971) divided causes of erosion into two major classes: dynamic and passive. The passive forces are those which weaken the levee's protective cover, but cause very minor direct erosion. Dynamic erosive forces include water erosion by waves, currents, and winds. The report indicates that the main dynamic erosive forces are currents and wave action on the river side of the levees and the principle causes of erosion are wind and boat-generated waves and currents due to tides and floods.

In a study of two channels--Georgiana Slough and the North Fork of the Mokelumne--the greatest source of erosive energy was floods. Wind waves are important on the outside of a bend, particularly if exposed to the southwest. In general, the river and tidal conditions are so overwhelming that the conclusions would be expected to hold, even with a large increase in boating and with the inclusion of other erosive forces.

The Tetra Tech study stated in good weather periods with no high winds or heavy rainfall, boats do present the most visual source of erosive energy. Areas with lots of boating activity receive large numbers of waves from the boats. Big, deep hulled boats create larger waves than small or flat hulled vessels. However, wind waves last 24 hours per day during high wind periods. Flood and tidal currents also persist throughout the year and the U.S. Bureau of Reclamation has experienced channel bank erosion on many channels in which boats are never present.

The impacts of currents, wind waves, and boat wakes vary greatly with each slough and its configuration, dimensions, orientation to the wind, and level and type of recreational use. A 1975 U.S. Geological Survey study in the Delta found that in a typical, narrow channel, subject to winter floodflows and heavy boat traffic (Georgiana Slough), about 20% of the total, annual energy dissipated against the levees could be attributed to boat-generated waves, about 10% to wind-generated waves, and 70% to shear stresses imposed by movement of water through the channel. In the winter when the floodflows occur and boat traffic is light, most erosion was caused by currents. In the summer, when floodflows are low and boat traffic is high, most--up to two-thirds--of erosion was caused by boat and wind-generated waves.

In a channel relatively unaffected by winter flood flows (False River), boat-generated waves were from 45% to 80% of the total energy, depending on wind movement assumptions in the computations. About 5,000 boats per year traveled each waterway.

The report says the findings cannot be applied to large channels in the western Delta where wind-formed waves probably generate almost all of the erosive energy. Ocean-going vessels (travelling to Ports of Sacramento and Stockton) produce waves whose energy far exceeds the energy levels studied. However, the findings for Georgiana Slough could be applied to other minor waterways, depending on the level of boat traffic and dimensions of the channel.

The most common method of protecting levees from erosion is the placement of rock riprap along the levee to the flood elevation level. It is now believed that riprap is not needed in smaller channels with lower current velocities or on the inner curves of channels bends where erosion is less severe. A major deterrent is the expense of placing riprap. A properly designed riprap revetment will not slump. Riprap should be placed over filter cloth or over a bedding and filter layer. Ongoing demonstration projects with alternative products (armorflex and tri-lock) appear to be effective against erosion and allow for more plant growth. However, these materials are very expensive compared to rock riprap.

When the levees were first constructed, narrow remnant islands were left which provided a buffer between the channel and the new levee (DFG, Draft MEA, 1993). Review of historic aerial photos show clearly that these islands (tule berms) are gradually disappearing, leaving the levees throughout the Delta exposed to direct erosion from tidal and flood currents and from wind and boat-generated waves.

d. Deformation. Levee foundations consisting of soft organic soils and peats are analogous to toothpaste; as the pressure on the tube increases, the toothpaste squeezes out. Similarly, when fill is placed over soft foundation soils, the soil deforms and bulges, migrating to the path of least resistance. As these softer blocks of peat squeeze out, cracks, fractures, or sinkholes can develop which encourages seepage and may lead to piping. To prevent the deformations from leading to a levee failure, large berms placed at the landside toe have been effective in controlling deformation, thus effectively capping and loading the soft peat. Levee work performed on Twitchell and Sherman Islands involved significant berm placement to control deformation and improve stability. Significant levee berm placement has also been accomplished on Holland and Webb Tracts.

e. Seepage. The constant elevation difference between the higher channel water surface and the lower ground surface of many Delta islands causes a continual seepage of water through and beneath the levees from the channels to the interior of the islands. Seepage tends to increase with time as land subsidence lowers the island ground surface. In some instances, saturated soils extend 1,000 feet into the islands. Visible flows occur in some places at the levee toe and in the toe drain ditches.

f. Sinkholes. Sinkholes are depressions on the landside of levees that are typically wet or filled with water. These holes can range in depth from a few inches to many feet and are between two and ten feet in diameter. Instances of the spontaneous development of sinkholes on levee back slopes are periodically reported on the deep peat islands.

An investigation was conducted on Sherman Island in 1991 to assess the causes of sinkholes. Potentially key characteristics identified at the Sherman Island sinkhole locations were:

- the presence of fissures in the peat below the levee fill.
- the existence of a relatively free flow of water through the levee from the river and into the sinkhole.
- the non-cohesive, easily erodible/transportable nature of the sandy levee fill.

g. Rodent Burrows. Rodent burrows, particularly those of beaver, muskrat, and ground squirrels, can threaten the integrity of a levee. Burrows in levees can weaken the levee section and contribute to levee failure by increasing the potential for piping. Vegetation on levee slopes makes it difficult to detect rodent burrows.

3. Seismic Issues.

As described in the Background Report on Environment, the Delta is in the vicinity of known faults, however, the recurrence interval along the faults is unknown. Due to the unique soil conditions, experts state that movement on the identified faults may impact Delta structures including levees. Research (California Geology, February 1985) shows that several bridge embankments failed along the Middle, San Joaquin and Mokelumne Rivers during the 1906 earthquake. Other quakes with some impacts to Delta levees include the Coyote Lake (1979), Livermore (1980), Pittsburg (1983), and Morgan Hill (1984) earthquakes.

As far as is known, earthquakes have not caused major damage to Delta levees; however, because levees in the central and western Delta are built partially on and of sand, a high potential for earthquake damage exits. Potential for earthquake damage diminishes further to the east. During an earthquake, water-saturated materials (sands) could be subjected to liquefaction, a reaction of soil and water, which resembles quicksand.

Adopted Findings:

F-1. Many Delta levees were originally built atop low natural levees along the waterways. The construction of higher levees was possible after the invention of the clamshell dredge. The levees were built of available material, without engineered designs.

F-2. The cost of constructing and maintaining the levees was born by the landowners and later by groups of landowners within reclamation districts. The reclamation districts are special districts created by the State that can assess landowners for the purpose of levee maintenance and drainage.

F-3. Large-scale federal flood protection and navigation projects include about 25% of the Delta levees. These "project" levees were designed and constructed to standards set by the federal government on a case by case basis and are largely maintained by the State or other local agencies.

F-4. Local Governments have responsibility to manage flood plains by controlling land uses and specific construction projects within the flood plains.

F-5. Guidelines for management of vegetation on levees promote grasses and limited tree growth allowing easy visual inspection and protection of the integrity of levees.

F-6. Where levees which are not routinely stripped of vegetation and become heavily vegetated, levee maintenance work will require removal of that vegetation; that loss of vegetation will require mitigation under the California Environmental Quality Act. Mitigation means replacement of the habitat that is removed, on site or nearby. The replacement ratio may be larger than the acreage removed.

F-7. For non-project levees to be eligible for FEMA assistance in a Presidentially declared disaster, reclamation districts must bring levees to the Flood Hazard Mitigation Plan Standards. Those standards currently are: one foot of freeboard above the 100-year flood frequency water-surface elevation; 16 foot crown width; water side slopes of 1.5 to 1; and land side slopes of 2 to 1 or flatter. For non-project levees to be eligible for Corps' assistance in a Presidentially declared Delta disaster levees must meet PL-99 standards. Those standards are: 1.5 feet above 100 year flood frequency water surface elevation; 16 foot crown width; water side levee slopes of 2 to 1; and land side levee slopes of 3 to 1 to 5 to 1, depending on height of levee and depth of peat.

F-8. Materials for levee construction and repair have routinely been dredged from adjacent waterways. Environmental regulations to protect endangered fish and other restrictions have limited access to this traditional source of material. Historically lower costs of using dredged material have been offset by increased regulatory costs. Other sources of levee maintenance material include: on-island deposits; quarries; construction projects, including habitat enhancement projects;

and spoils form authorized maintenance dredging projects by ports or flood control districts.

F-9. Historically, all costs of levee maintenance fell on the landowners, even though multiple beneficiaries of the levees have been identified. Currently, assistance from the State is available to reclamation districts for maintenance of non-project levees under the Delta Levee maintenance Subventions Program, due to expire January 1, 1999. No federal funds are provided for the State's levee maintenance program. Federal property owners are not subject to reclamation district assessments. No federal or State funds are available to share routine maintenance costs of most Project levees with the local agency responsible for that maintenance.

F-10. To participate in the State-funded levee maintenance program, the reclamation districts are required to prepare additional environmental analysis, prepare more detailed engineering plans, obtain additional state and federal permits, and provide mitigation to offset unavoidable losses of habitat. These conditions have resulted in higher per mile costs of levee maintenance.

F-11. Due to the many State and federal regulatory agencies with authority in the Delta, lack of coordination between those agencies, and continually evolving issues, the length of time to obtain approvals for levee maintenance ranges from approximately six months to several years.

F-12. No special funds have been reserved exclusively for emergency levee repair work carried out by the State or reclamation districts. The State has several means to accomplish emergency work including Water Code Section 128, the California Emergency Services Act, interagency agreements, and funding from SB 34. Banks have recently indicated reluctance to accept warrants from reclamation districts limiting options for funding emergency work.

F-13. Loss of Delta levees could result in loss of life; lowered water quality for water diverted by local water systems and for export through the State and federal water systems; loss of freshwater due to increased evaporation; loss of property, including crops and structures; and loss of habitat. Rodent dens and tunnels, particularly those created by beaver and muskrat, can adversely affect levee stability and are thought to have been the cause of numerous levee failure.

F-14. Although no "active" faults have been identified in the Delta planning area, many Delta levees are built upon materials that would be inherently unstable in the case of a seismic event. A zone of buried thrust faults has been identified north-south along the western Delta; this type of fault was the source of the recent Northridge earthquake. Although no Delta island has flooded as the result of seismic activity, Delta levees could suffer major damage in the event of a large earthquake.

F-15. Delta levees are subject to a number of factors, which adversely affect the stability of the levees. Many of the levee foundations are unstable materials. The subsidence of the peat soils on many of the islands has resulted in increased pressure on the levees from water in the adjacent channels. The levees are constantly subjected to erosion from natural and created causes including; flood flow, tides, wind waves, vessel wakes, and waters drawn into the State and federal water projects.

Levee failures can be identified principally by the major mechanisms of failure (stability, overtipping, or subsurface seepage erosion), then more specifically by contributing factors (subsidence, cracks, and fractures, encroachments, waterside erosion, deformation, seepage, sinkholes, rodent burrows, and poor foundation conditions).

Adopted Policies:

P-1. **Delta levees shall be maintained to protect human life, to provide flood protection, to protect private and public property, to protect historic structures and communities, to protect riparian and upland habitat, to promote interstate and intrastate commerce, to protect water quality in the State and federal water projects, and to protect recreational use of the Delta area. Delta levee maintenance and rehabilitation shall be given priority over other uses of the levee areas. To the extent levee integrity is not jeopardized, other uses, including support of vegetation for wildlife habitat, shall be allowed.**

P-2. **If levee guidelines are needed, local governments shall adhere to guidelines for federal and local levee maintenance and construction at a minimum as stipulated in the Flood Hazard Mitigation plan guidelines, and set longer term goals of meeting PL-99 Standards. If vegetation standards are needed, local governments shall adopt the adopted vegetation guidelines that promote native grasses and limited vegetation on specific areas of the levee.**

P-3. **Through flood ordinances based on FEMA model ordinances, local government shall carefully and prudently carry out their responsibilities to regulate new construction within flood hazard areas to protect public health, safety, and welfare. Increased flood protection shall not result in densities beyond those allowed under zoning and General plan designations in place on January 1, 1992, for lands in the Primary Zone.**

P-4. **Existing programs for emergency levee repair should be strengthened and better coordinated between local, State, and federal governments and shall include: interagency agreements and coordination; definition of an emergency; designation of emergency funds; emergency contracting procedures; emergency permitting procedures; and other necessary elements.**

P-5. **Local governments shall use their authority to control levee encroachments that are detrimental to levee maintenance.**

Levees Recommendation:

R-1. *Levee maintenance, rehabilitation, and upgrading should be established as the first and highest priority of use of the levee. No other use whether for habitat, trails, recreational facilities, or roads should be allowed to unreasonably adversely impact levee integrity or maintenance.*

R-2. *Landowners, through reclamation districts, should pay a portion of levee maintenance costs. The overall citizenry of California and the United States that benefits from the state and federal water projects, commerce and navigation, travel, production of crops, recreation, and protection of fish and wildlife habitat should also pay a substantial portion of the cost of maintaining the Delta levees. Reclamation districts should evaluate new programs of determining assessments on mineral leases and other beneficiaries.*

R-3. *Due to the difficulty in identifying all the beneficiaries of both State and federal levees and the entities that cause adverse impacts to the levees, the simplest way to collect the funds needed to maintain the levees would be through non-fundable allocations from both the State and federal government to fund regular, on-going levee maintenance.*

R-4. *Where efficiencies of scale would result in cost savings and levee systems of two or more reclamation districts provide protection to the same area, the State and other regulatory agencies should consider approval of requests made by reclamation districts for such consolidation.*

R-5. *If funding is made available to the reclamation districts for levee maintenance, mitigation for removal of vegetation required to maintain existing levees should be coordinated through a memorandum of understanding between reclamation districts, State, and federal agencies, which results in minimal fiscal impacts to reclamation districts and which will result in "no net long term loss" of habitat in the legal Delta.*

R-6. *A "clearinghouse" for material suitable for levee maintenance should be created to assist in distributing appropriate materials to sites slated for maintenance work. Materials which have value for levee maintenance work, such as materials routinely dredged from Delta channels or materials otherwise excavated from within the delta area, should be reserved first for levee maintenance work. Other uses should be considered only if the material is not needed or is unsuitable for levee maintenance work. Regulations should establish priorities for in-Delta use of soil excavated from within the Delta.*

R-7. *Study appropriateness of materials from other sources for levee maintenance and repair, similar to the Long Term Management Strategy prepared for the San Francisco Bay region.*

R-8. *To lower levee maintenance costs, streamlined permitting systems for authorization of dredging for levee maintenance and rehabilitation work,* *including the improvement of wildlife habitat and habitat mitigation sites, and for levee upgrading to mandated standards to protect public health and safety, should be instituted, with one state agency designated as lead agency and one federal agency designated as lead agency. Federal agency concurrence in such designations should be obtained.*

R-9. The program for emergency levee repair should be strengthened. The program should include: definition of an emergency; designation of emergency funds; emergency agency to provide immediate response to floodfight, close levee breaks, and dewater flooded areas where local agencies are unable to respond. An emergency program should develop a funding program to assist reclamation districts that are unable to pay such costs.

R-10. Maintain an inventory of the current status of Delta levees meeting various standards (HMP; PL-99; etc.)

R-11. Maintain an inventory of channel areas where toxic materials have been identified.

R-12. Levee maintaining agencies and fish and wildlife agencies should continue to cooperate to establish appropriate vegetation guidelines. Continuation of the SB34 Program with its incentive funding for mitigation should be supported as the best way to accomplish the goals of levee maintenance with no net long term loss of habitat.

R-13. As much as feasible, levees should be designed and maintained to protect against damage from seismic activity. Those standards should not promote increased intensity or density of use beyond those designated as of January 1, 1992.

R-14. Support on-going U.S. Army Corps of Engineers studies and programs that could provide funding, flood protection, and environmental restoration on Delta islands, and support further involvement to improve regulatory streamlining and study beneficial reuse of dredged material.

Appendix A: Delta Plans and Studies

1973, DWR, Delta Levees: What is their future? A presentation of alternative courses of action for the Sacramento-San Joaquin Delta levees. Prepared in the same year as Delta Master Recreation Plan; incorporates public access on levees and 49 high-use locations for recreation.

1980, Madrone Associates for Department of Fish and Game/U.S. Fish and Wildlife Service, Delta Wildlife Habitat Protection and Restoration Plan.

1981, DWR, Sacramento-San Joaquin Delta Levees Study (Fourth Interim Report to the Governor and the California State Legislature). Interim report being prepared as part of the 1982 DWR-Corps study.

1981, U.C. Davis and DWR, The Future of the Delta- Proceedings of a Conference (March 16-17, 1981).

1982, Assembly Office of Research, Sacramento/San Joaquin Delta Dilemma. Prepared after floods of 1982; recommends formation of Emergency Delta Task Force. Includes study of land ownership.

1982, Corps of Engineers, Draft Feasibility Report and Draft Environmental Impact Statement: Sacramento-San Joaquin Delta, California. Master plan for levee upgrades, creation of wildlife refuge, and creation of recreation sites.

1983, Emergency Delta Task Force, Recommendations to the Assembly Water, Parks, and Wildlife Committee, which was authorized by the Assembly by House Resolution 40 of 1982. Outlines preferred Delta levee restoration plan, identifies beneficiaries of Delta resources, develops equitable cost-sharing formula, investigates funding sources.

1986, DWR, Sacramento-San Joaquin Delta Emergency Water Plan Required by AB 955, Chapter 1271. Plan for an emergency that would allow the Central Valley Project, State Water Project, East Bay Municipal Utility District and Contra Costa Water District to continue or to quickly resume exporting or delivering usable water.

1988, DWR, South Delta Water Management Program. One of three reports on water management issues in the Delta (North, South and West).

1990, DWR, Actions and Priorities: Delta Flood Protection Act: Eight Western Delta Islands.

1993, Bay-Delta Oversight Council, Briefing Paper on Delta Levees and Channel Management Issues.

REFERENCES

Assembly Office of Research, Sacramento/San Joaquin Delta Dilemma, 1982.

Bay-Delta Oversight Council, Draft Briefing Paper on Delta Levee and Channel Management Issues, 1993.

California Geology, February 1985.

Chan, Sucheng, This Bitter Sweet Soil, 1986.

Department of Fish and Game, Draft Sacramento-San Joaquin Delta Master Environmental Assessment, 1993.

Department of Water Resources, Actions and Priorities, Eight Western Delta Islands, 1990.

Department of Water Resources, Bay Delta Oversight Council Delta Tour, 7/23/93.

Department of Water Resources, Bulletin 192, Plan for Improvement of Delta Levees, 1975.

Department of Water Resources, Delta Atlas, 1993.

Department of Water Resources, Delta Connection, November 1992.

Department of Water Resources, Delta Levees (prepared for the Bay Delta Oversight Council), 1993.

Department of Water Resources, Delta Levees: What is Their Future?, 1973.

Department of Water Resources, Delta Levees Investigation Economic Inventory, 1993.

Department of Water Resources, Interim Report on the Status of Sacramento-San Joaquin Delta Flood Hazard Mitigation Plan, 1990.

Department of Water Resources, Draft Review of Seismic Stability Issues for Sacramento-San Joaquin Delta Levees, 1993

Department of Water Resources, Sacramento-San Joaquin Delta Emergency Water Plan, 1986.

Dillon, Richard, Delta Country, 1982.

Foott, Roger, Draft Lessons from Levees, 1993.

Kjeldsen, Chris K. and John R. Arnold, Habitat Values, 1991.

Madrone Associates, Delta Wildlife Habitat Protection and Restoration Plan, 1980.

Reclamation Board, 1991.

Reclamation Board, Interim Guide for Vegetation on Flood Control Levees under Reclamation Board Authority, 1988.

Sacramento County, Floodplain Management Ordinance Companion Document, 8/9/93.

San Francisco Estuary Project, An Analysis of the Beneficial Uses of Dredged Material at Upland Sites in the San Francisco Estuary, 1994.

SB 34, Delta Flood Protection Act, 1988.

Schell, Hal, Dawdling on the Delta, 1979.

State Lands Commission, Delta-Estuary California's Inland Coast, 1991.

State Lands Commission, Proceedings of Public Hearing on Saving the California Delta: Exploring the Management Options, 1991.

Tetra Tech, Causes of Levee Damage in the Sacramento-San Joaquin Delta, 1971.

United Stated Geological Survey, Evaluation of the Causes of Levee Erosion in the Sacramento-San Joaquin Delta, California, 1975.

United States Army Corps of Engineers, Code of Federal Regulations, Section 208.10, Local Flood Protection Works: Maintenance and Operation of Structures and Facilities, 7/1/89 Edition.

United States Army Corps of Engineers, Environmental Assessment/Site-Specific Review for Contract 42A of the Sacramento River Bank Protection Project, 1993.

United States Army Corps of Engineers, Draft Sacramento River Flood Control System Evaluation, 1993.

United States Army Corps of Engineers, Draft Feasibility Report and Draft Environmental Impact Statement, Sacramento-San Joaquin Delta, 1982.

Water Education Foundation, Layperson's Guide to the Delta, 1993.

Water Education Foundation, Layperson's Guide to Flood Management, 1990.

###